NASA Technical Memorandum 78578

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Wildlife Monitoring Program Plan

Paul Sebesta and Roger Arno

(NASA-TM-78578) WILDLIFE MONITORING PROGRAM PLAN (NASA) 233 p HC A11/MF A01 CSCL 06C

N79-23626

Unclas
G3/51 25154

April 1979

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Paul Sebesta
Roger Arno, Ames Research Center, Moffett Field, California

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Ames Research Center
Moffett Field, California 94035

PREFACE

In 1969 the National Academy of Sciences (NAS) assembled a panel of scientists to "look anew at the foundation of space biology...." Wildlife behavior and ecological relationships were among the subjects discussed, and recommendations were made for "a program for satellite tracking of free ranging animals" and for "a panel composed of experts in the various branches of ecology and in the use and capabilities of multispectral sensing devices, to be convened to carry out an evaluation in depth of this promising application."

Shortly after the Academy report was published NASA launched the Nimbus 4 sattelite carrying the Interrogation, Recording and Locating System (IRLS) which was used to detect a free roaming elk. The tracking of the elk by NASA, Department of the Interior and Smithsonian Institution was successful. A subsequent study carried out for NASA revealed that a large number of agencies and scientists were interested in the use of satellite techniques to monitor wildlife.

In accordance with the National Aeronautics and Space Act of 1958, the recommendations of the NAS, and the interest expressed by Federal and State agencies, and representatives of the scientific and technological community, meetings held in December 1972 and in February and April 1973 to discuss national goals and activities in wildlife resource management. The needs of those agencies which have statutory requirements to manage wildlife resources and NASA's capabilities in adapting aerospace technology to monitoring wildlife were studied, and plans were undertaken to hold a workshop on wildlife monitoring in response to national needs. The workshop was held at Santa Cruz in September 1973 and resulted in this report.

ACKNOWLEDGEMENTS

This document is the end product of the contributions of numerous individuals from throughout many government agencies, private industries, and institutions of higher learning. Appendix A also lists in detail all the researchers involved with the initial gathering of needs and technical information associated with the Wildlife Monitoring Program at its inception.

We would like to acknowledge the efforts of the individuals that processed and created the program plan from the background material.

Mr. Roger Arno – Space Applications Branch, NASA ARC
Dr. John Billingham – Chief, Biotechnology Division, NASA ARC
Mr. Charles Cote – Chief, Data Collection Systems Branch, NASA GSFC
Mr. Jerry Deerwester – Chief, Space Applications Branch, NASA ARC
Mr. Paul Sebesta – Special Assistant for Terrestrial Ecology, Life Sciences, NASA ARC
Dr. Richard Simmonds – Flight Experiments Office, NASA ARC
Dr. John Tremor – Assistant Chief, Earth Science Applications Office, NASA ARC
Mr. Charles Vaughn – Applied Sciences Directorate, Wallops Station, NASA
Dr. David Winter – Deputy Director of Life Sciences, NASA ARC
Mr. Al Worden – Chief, Systems Studies Division, NASA ARC

TABLE OF CONTENTS

LIST OF FIGURES

Figure	Title	Page

LIST OF TABLES

SUMMARY

This document presents a plan for integrating the various requirements for wildlife monitoring with modern aerospace technology. The Wildlife Monitoring Program Plan is responsive to the need for wildlife conservation, protection, and management and recognizes the legal requirements embodied in almost a hundred legislative acts. Specific wildlife monitoring tasks and hardware development programs are designated in this plan to show the user agencies how they can meet their goals of maximizing the commercial, recreational, and cultural benefits of our wildlife resources. NASA's participation is restricted to demonstrating the techniques of aerospace technology and precludes operational monitoring or management tasks.

A careful study of the user agencies' wildlife management objectives made clear the need for quantitative models relating the health, vigor, and population dynamics of the animals in relation to natural perturbations in the natural environment or those induced by man. The immediate need is for data on animal location, numbers, habitat, and behavior/physiology in order to construct these management models. Parallel to the development of management models, efforts in monitoring instrumentation, communications equipment microminiaturization, and data interpretation are also required.

To verify the monitoring methodology and keep the tasks to a manageable level, the Wildlife Monitoring Program Plan is based on an evolutionary growth from domesticated animals and larger animals to smaller, more scarce, and more geographically remote species. Animals were selected for initial investigation largely on the basis of the 1973 Santa Cruz Summer Study on Wildlife Monitoring (included as appendix A), with additional consideration given to those animals that are more easily handled, those for which more experience has been accumulated, or those that are more acceptable to the general public. The animals chosen for initial investigation are cattle, gray whale, walrus, dog, and duck. The scope of the program will grow, for instance, from whale to porpoise, to large fish and then to smaller fish. In another instance, it will expand from dogs to wolves, through bears, cougars, and other predators. As the handling techniques and technology are developed for each animal, the monitoring and management tasks will be interfaced with user agencies for the eventual operational phase. The major NASA effort is therefore initially restricted to demonstration programs on only five principal species, where the value of using aerospace technology can be realized with the maximum chance of success.

The Wildlife Monitoring Program involves laboratory investigations of animal behavior and physiology as well as electronics research and development. These efforts support the monitoring tasks undertaken by field parties, remote field stations, aircraft, and satellites. Each data collection method, operating in its own unique way, contributes to the total information-gathering process. Used to best advantage, satellites will gather synoptic data on habitat and meteorology. Satellites in sun-synchronous and similarly low orbits will also be used to locate and track animals. At the same time, geosynchronous satellites can serve the unique function of continuously relaying data over much of the earth's surface. Aircraft will be used largely to image habitats and, in some cases, image

animals directly. Field stations will be used principally to gather meteorological data, but they can also be used as data relay links or as reference points in animal tracking. Field parties will be required for ground truth and behavior monitoring and they will also be used to perform such functions as animal tagging, harnessing, or maintaining field stations. The program will be carried out at Ames Research Center, Goddard Space Flight Center, Johnson Space Center, and the facilities at Wallops Station.

The development of technological and management methods for wildlife monitoring could involve NASA to the extent of $7 or $8 million over the next 15 years. The funding would reach a peak in the late 1970's and decline through the 1980's. About 60 percent of that effort would be in the area of hardware research and development, the rest for gathering and interpreting data. It appears that about 60 percent of the hardware design (e.g., satellite technology, electronic micro-miniaturization, etc.) could be used to satisfy animal requirements in a common modular fashion.

INTRODUCTION

The Wildlife Monitoring Program Plan presented in this document integrates the growing requirements for ecological management with the newest techniques in biological science and aerospace technology. The increasing need for ecological management stems chiefly from the pressures of a world population that grows not only in numbers but in standard of living. As man's perturbation of the ecological system expands, there is an increasing need for management of natural resources by controlling their use and consumption, and for guarding against their destruction through pollution or other ecological imbalances. The foundation of ecological management is understanding, and the first step in that understanding is monitoring. It is therefore the intent of this document to present a systematic approach to one aspect of ecological management, the problem of rational wildlife monitoring.

The Wildlife Monitoring Program Plan draws on user needs expressed in international agreements, federal and state legislation, and the stated requirements of government agencies. It incorporates the espoused views of various special interest groups, industry, the scientific and academic communities, and individuals. Much of this background material was assembled at the 1973 Santa Cruz Summer Study on Wildlife Monitoring (appendix A).

The Program Plan describes the program objectives; it summarizes the needs, requirements, and program justification, as well as the current program and technology status; it describes the selected demonstration program and its implementation (i.e., specific tasks to be performed); and it suggests a plan for management and NASA involvement.

It is emphasized that a systematic approach, as intended here, does not dictate that all aspects of interaction between wildlife species and the environment be handled simultaneously. Rather, the program is designed to demonstrate the feasibility of implementing concepts of monitoring by concentrating on selected animal species. Such demonstrations of the application of aerospace technology to wildlife monitoring, and the understanding of ecological interactions gained therefrom, should permit the generation of rational management approaches that can be used by the various user agencies to develop operational management techniques.

It is recognized that the subject of wildlife management is so extensive and so subjective that a program plan could occupy volumes. This report is not intended therefore to treat all aspects of wildlife management in detail. Many strategic questions (e.g., which animal species have the most aesthetic value) cannot be considered until a rational program is implemented and more data are available. For these reasons, many tactical questions such as those dealing with specific modes of operation (e.g., sensor wavelength or specific satellites) are not discussed here.

OBJECTIVES

The purpose of the Wildlife Monitoring Program is to provide a firm technological and system-oriented approach to satisfy user requirements in the area of wildlife monitoring and, ultimately, ecological management. It is, further, the intent of the program to make maximum use of technology and techniques derived from aerospace research and development, and to test each method for appropriateness and practicality in monitoring a limited sample of animal species. To meet these broad objectives, a set of sub-objectives is defined as follows:

1. To determine which physiological and behavioral parameters best indicate the health and vigor of a species.
2. To determine which environment and habitat characteristics can be used to describe the state of the ecological system and its dynamics.
3. To monitor the location, physiology, behavior, and habitat of selected animal species and collect appropriate data for guiding research and meeting the specific needs of the user agency.
4. To determine the appropriate role of aerospace technology (such as communications, electronic microminiaturization, and remote sensing) in monitoring wildlife resources.
5. To recommend technological research and development programs that best satisfy the requirements for monitoring wildlife.
6. To develop environmental and management models and document the data and techniques applicable to environmental management.
7. To orient potential user agencies by soliciting their collaboration and direct aid in the form of manpower and funds.

The relationship of the Wildlife Monitoring Program to the fundamental requirements and capabilities is illustrated in figure 1. This figure shows where aerospace technology and systems management can interface with the user agencies and their needs as defined in appendix A.

JUSTIFICATION

Our natural resources are all closely related, each an integral component of the ecosystem, a component of the biosphere. A significant alteration of one component will influence the

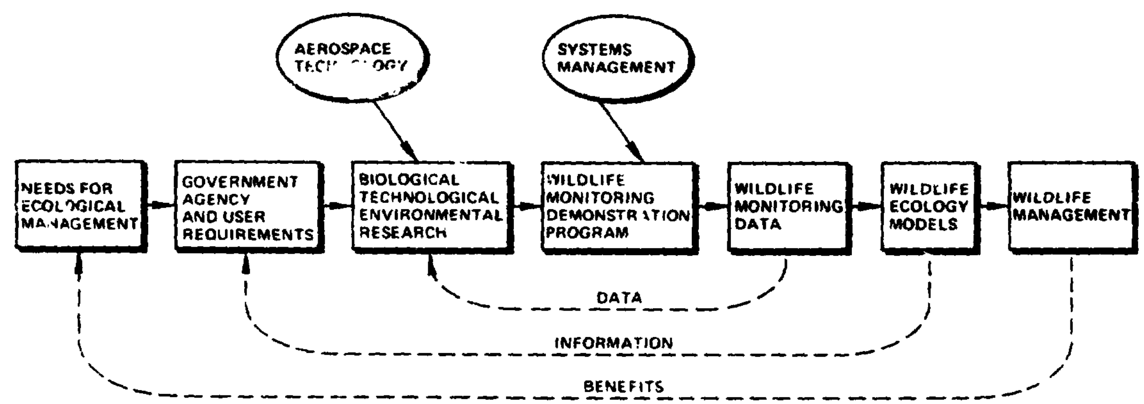


Figure 1.– Wildlife Monitoring Program structure.

equilibrium of the entire system. Each resource plays a role in maintaining the health and stability of our global life-support system.

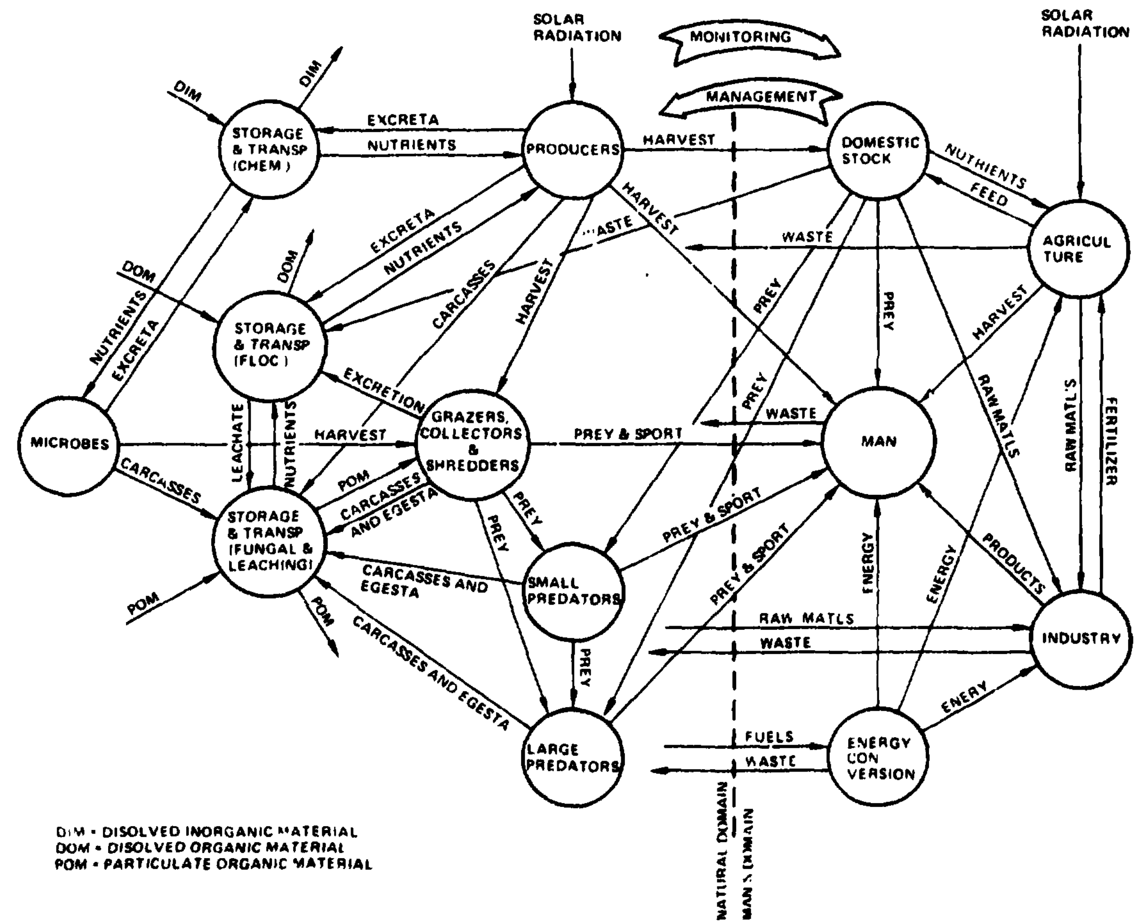
Man has brought about many changes in the natural environment by clearing land, planting farmlands, building cities, excavating for resources, and disposing of waste. Many of the changes are beneficial to man, others are detrimental. Man's encroachment on the wilderness areas and his dominance over certain pests has resulted in the availability of more mineral and agricultural resources, but it has also created an increasing pollution problem and a growing list of endangered animal species.

The relationship between man and a portion of the ecosystem is shown in figure 2. The figure illustrates, first of all, man's impact on the natural balance within the environment because nature must absorb man's waste materials and energy. In addition, man depends heavily on nature to supply animal, vegetable, and mineral resources. For example, there is a delicate balance in the network between man's domestic livestock, natural vegetation, wild grazers, and predators. Man has killed many of the cougars and wolves to protect domesticated animals. This action, however, increases the number of natural grazers and can aggravate the competition between natural and domestic animals for rangeland food sources. If man is to maintain adequate food supplies as well as protect natural animal species, some very sophisticated management models and techniques must be developed.

The importance of maintaining an ecological balance is exemplified by the food energy chain that links the basic source of energy in absorbed sunlight with higher animals that are man's major source of proteins. A serious break in any link in the chain which yields the larger fish for man's diet could destroy a process that already suffers from low efficiency (fig. 3). A case of misguided wildlife management, namely, the removal of deer predators from the Grand Canyon area, is shown in figure 4. The size of the deer herd is actually lower than it should be, or might be, if more data had been available or if the correct indicators had been heeded.

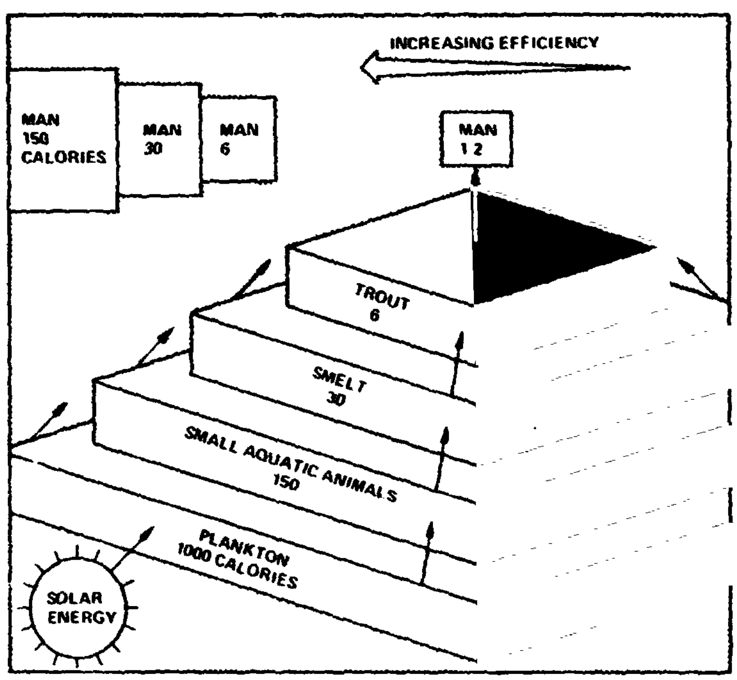
Some of the benefits to be gained by a rational program of wildlife management are listed below.

1. Conserving, restoring, and protecting endangered wildlife species.
2. Maximizing animal harvest for commercial uses such as for food, fur, skins, oils, etc.
3. Maximizing animal species for hunting, fishing, entertainment and other recreational purposes.
4. Controlling agricultural damage by animals.
5. Controlling the spread of disease by animals.
6. Controlling insects and other pests with animals.
7. Maintaining a source of animals for research and other scientific reasons (such as methods of navigation, biology, behavior, medicinals, etc.).
8. Preventing damage and loss of life due to aircraft collision with birds.



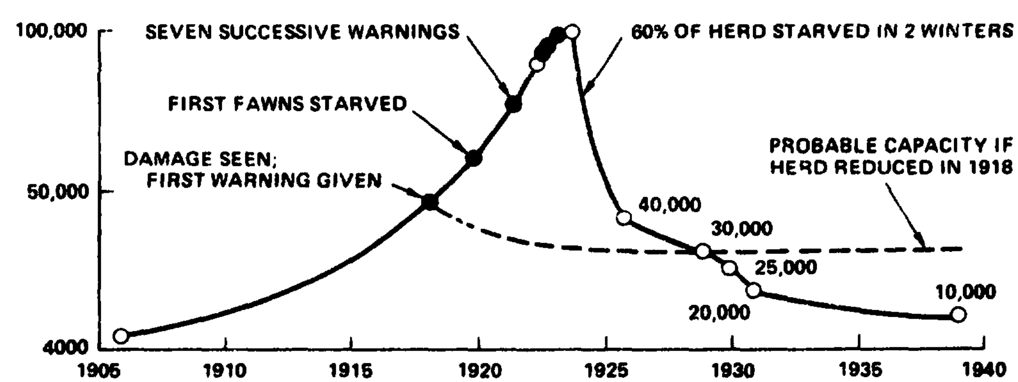
REFERENCE 13
& OTHER SOURCES

Figure 2.— Man's interface with the natural environment.



ENERGY PYRAMID IF MAN WERE THE ONLY OTHER LINK IN THE PLANKTON MAN FOOD CHAIN, MORE THAN 100 TIMES THE ENERGY WOULD BE AVAILABLE TO HIM THAN AS THE TERMINAL LINK OF THE PLANKTON AQUATIC ANIMAL-SMELT-TROUT-MAN FOOD CHAIN (AFTER LAMONT C. COLE, "THE ECOSPHERE," SCI AMER, 198, 1958

Figure 3.-- Food energy chain.



REMOVED FROM KAIBAB:

				TOTALS
COUGARS:	600 (1907-17)	74 (1918-23)	142 (1924-39)	816
WOLVES:	11 (1907-23)		(LAST WOLF 1926)	30
COYOTE:	3000 (1907-23)		4388 (1923-39)	7388
				8234

THIS IS A CLASSIC EXAMPLE OF A WILDLIFE MANAGEMENT DECISION BASED ON INADEQUATE INFORMATION. AN INTENSIVE PREDATOR REMOVAL CAMPAIGN PRECIPITATED AN ERRUPTION OF THE MULE DEER HERDS. IMPENDING DISASTER WARNINGS WERE IGNORED. SYSTEMATIC DATA COLLECTION AND THE USE OF MANAGEMENT MODELS CAN AVOID THESE DISASTERS'

Figure 4.– [illegible]r population with predator removal.

9. Understanding natural indicators of potential problems for man such as mercury poisoning, hazardous pesticide levels, etc.

10. Understanding the habitat conditions so that corrective actions can be taken to restore the ecology.

Needs and Requirements

Information gathered in a comprehensive Wildlife Monitoring Program is applicable to improved commercial harvests of wildlife resources, some of which are major factors in the world food supply. This information will also be important in the management of noncommercial wildlife resources that contribute to a very large and significantly increasing range of recreational, aesthetic, and educational uses. These include the relatively stable demands for hunting and fishing and the rapidly expanding nonconsumptive uses of wildlife, including tourism. Many species also serve as sensitive indicators of environmental degradation such as pollution.

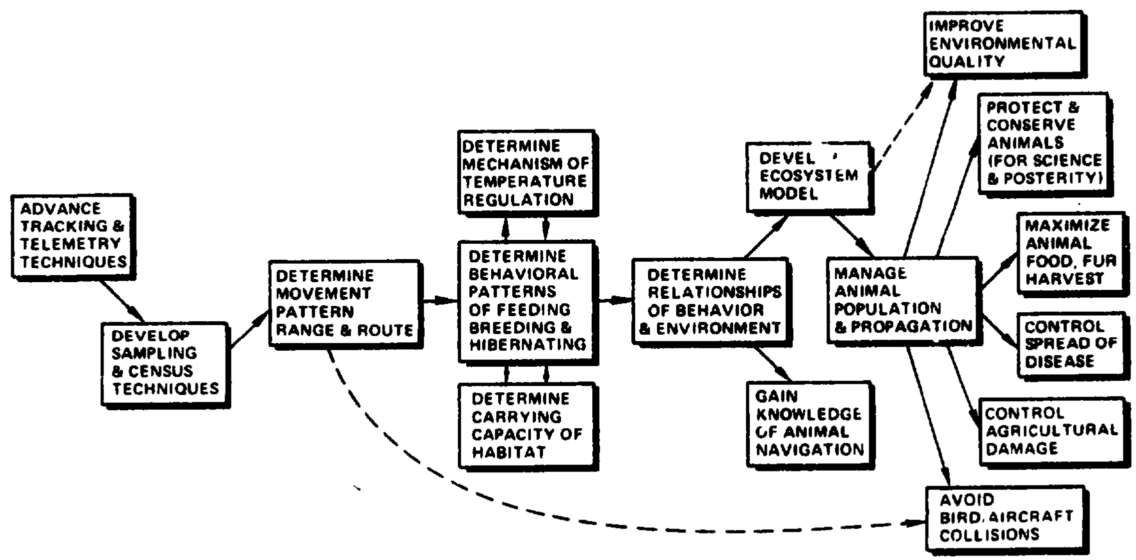
The basic wildlife monitoring user information needed to produce the aforementioned benefits is given below (Santa Cruz report, appendix A).

- Animal censusing and population dynamics; a continuing check on the health and vigor of animals and their populations
- Location of animals to determine migratory paths, speed and direction of movement and changes in movement patterns during stages of their life history
- Habitat characterization; description, mapping, and determination of the boundaries of the animals' ranges
- Physiology baselines for detecting changes relating to health and vigor; physical analogs of biologic systems
- Behavior within the habitat; feeding and breeding and reaction to environmental changes

Figure 5 shows the relationships between the information needs and eventual benefits.

The justification for wildlife monitoring from an economic standpoint alone is substantial. The costs of such a program are imperceptible compared to world fishing activities worth billions of dollars annually, or the U.S. domestic grazing animal inventory valued at a billion dollars, or the loss of resources and property due to animals which amounts to hundreds of millions of dollars annually, or the loss of many millions of dollars worth of natural resources due to pollution, insect pests, and disease.

The dollar magnitudes of some of the ecology and wildlife activities are shown in figure 6 to be very substantial, especially in comparison with potential wildlife monitoring programs sponsored by NASA. For example, a research investment of 1 percent of the value of the annual world fishery production would be over $200 million a year. The estimated U.S. Federal and state annual expenditure on wildlife management is now $140 million. Federal funding for environmental



*ADAPTED FROM "RATIONALE FOR ANIMAL TRACKING AND BIOTELEMETRY" SATELLITE WILDLIFE RESEARCH PROGRAM–FINAL TECHNICAL REPORT, NO TR 1424, LESTER E GARVIN ET AL, RAYTHEON COMPANY, 29 MARCH 1972

Figure 5.– Motivation for animal tracking and biotelemetry.*

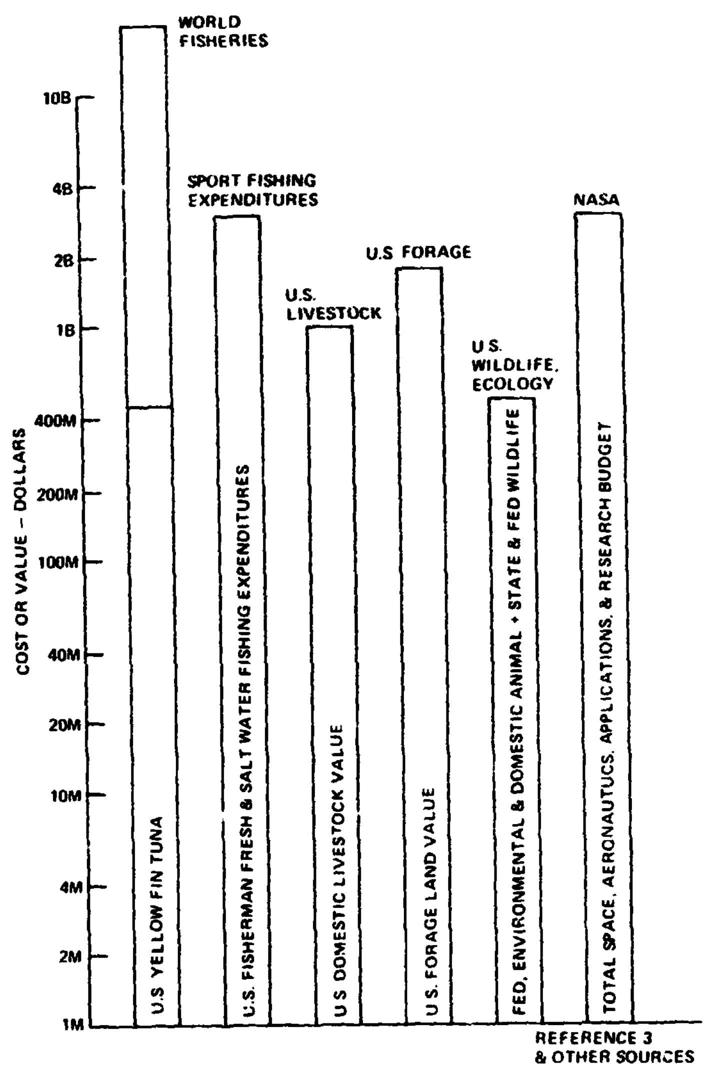


Figure 6.– Monetary magnitudes in wildlife resources.

enhancement activities involving resources in FY 73 was about $340 million. The annual cash worth of wildlife resources can be measured in billions of dollars.

Our growing population and the attendant increasing demand for resources has created, and will continue to create, pressure on the use of land and on wildlife. Some of the demands, projected to the year 2000, are shown in figure 7 compared to 1960 levels. Many resource consumer demand levels are expected to double or triple, even though the population will not quite double. The recreational land squeeze is especially serious, with demands expected to increase by a factor of 4.

World fishing activity has already tripled from the early 1950's level despite the loss of several species due to pollution and the drastic decline of others (such as whales and Peruvian anchovetas) due to overfishing. Some of these trends are indicated in figure 8. Even though agricultural land area will not increase greatly, the demand of the burgeoning world population for food will not likely be met even with expected yields per acre doubling between 1960 and 2000 (fig. 9). The demand for greater food production and crop yields will place increased strain on wildlife because of the increased uses of pesticides, other chemical pollutants, and the conversion of wildland to agricultural land.

Legislation and Agreements

Much of the 2250 million acres within the U.S. borders is undeveloped wildlands. The Federal Government alone owns 1/3 (761 million acres), and state and local governments own much more. About 1/6 (370 million acres) is designated as crop land. As illustrated in figure 10, much of the Federal land falls under the jurisdiction of the Bureau of Land Management, which has responsibility for an area equivalent to Alaska and California combined. (Coincidentally, much of the land is, in fact, in Alaska.) The U.S. Forest Service has control over an area the size of Texas, while the U.S. Fish and Wildlife Service and the U.S. Park Service control 28 and 24 million acres, respectively (equivalent to Pennsylvania and Indiana).

In 1960, America's total land requirement for all uses (cropland, rangeland, forests, recreation areas, urban land, transportation, wildlife refuges, and reservoirs) was 1815 million acres. (There are 1904 million acres in the coterminous U.S.) By the year 2000, the requirements will outstrip the availability. Obviously, the management of U.S. lands is critical, and the selected 90 pieces of Federal legislation shown in figure 11 reflect this.

The seriousness of wildlife and natural resource management is also reflected in the increasing volume of international agreements with time. The number of signing nations and dates of wildlife agreements are shown in figure 12. Natually, many of these pertain to fishing and marine mammals.

The U.S. Government has substituted the word "threatened" for the previous designations of "rare and endangered." In addition to the newly passed Endangered Species Act of 1973, there have been a number of Federal acts designed to protect these animals: Endangered Species Protection Act of 1966 (80 Stat. 926), Endangered Species Conservation Act of 1969, Migratory Bird Treaty Act (16 U.S.C. 703-711), Bald Eagle Act (16 U.S.C. 668-668-d), Marine Mammal Protection Act

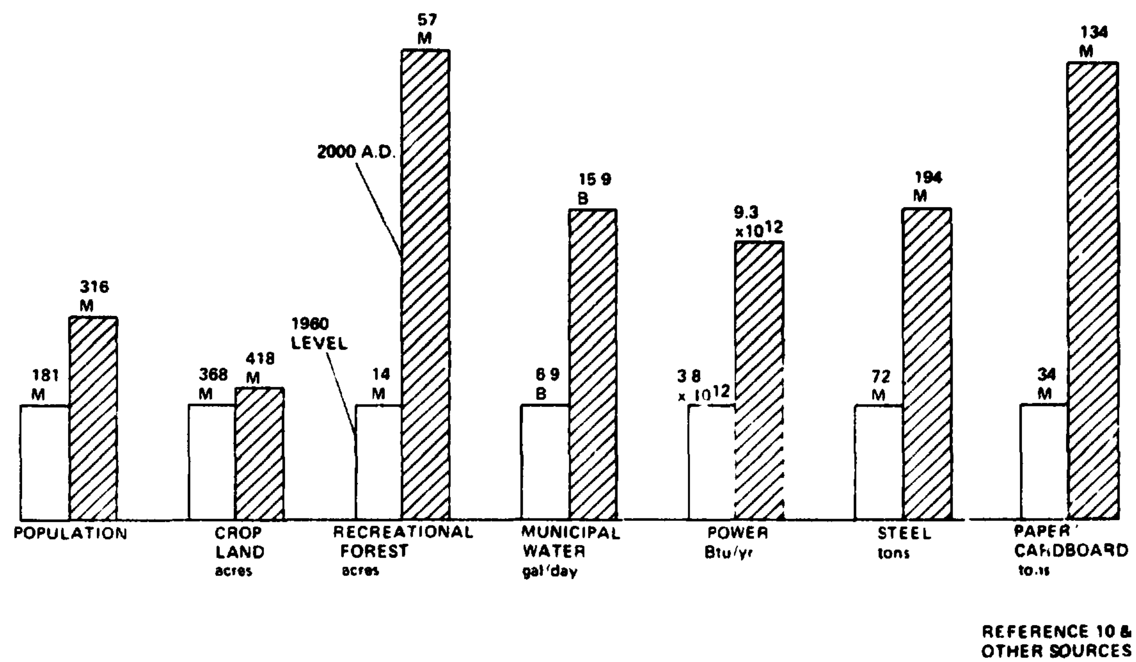


Figure 7.– U.S. consumer demand projections.

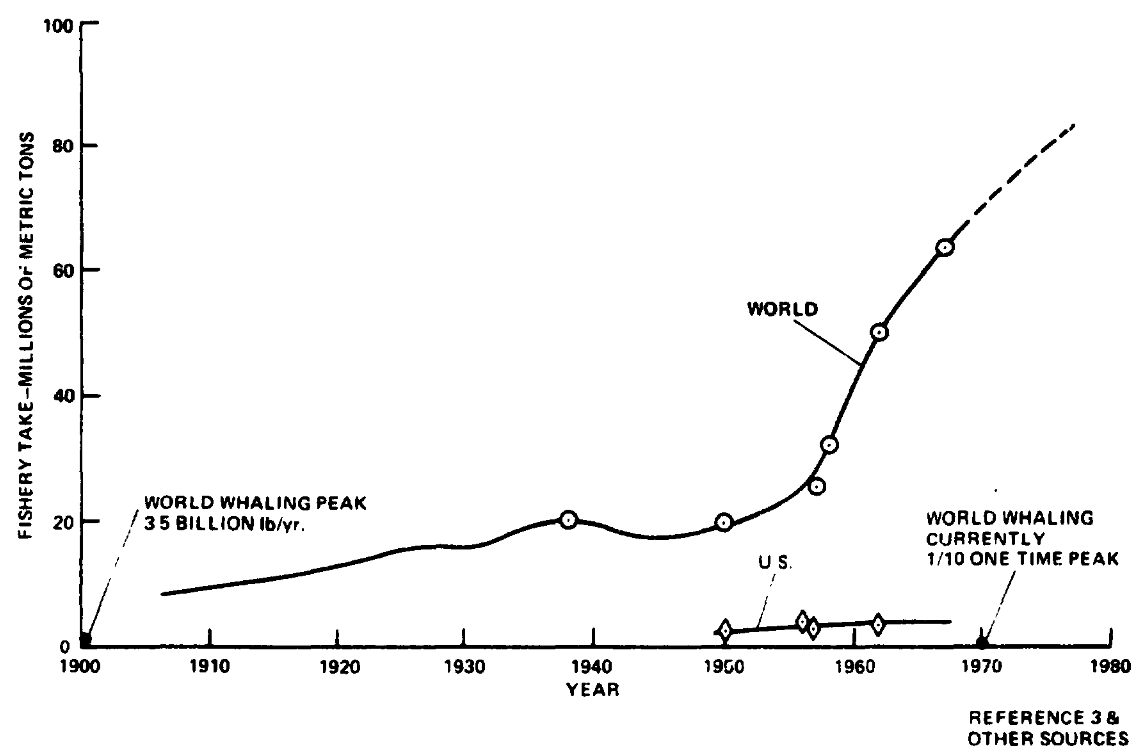


Figure 8.– World fishery production.

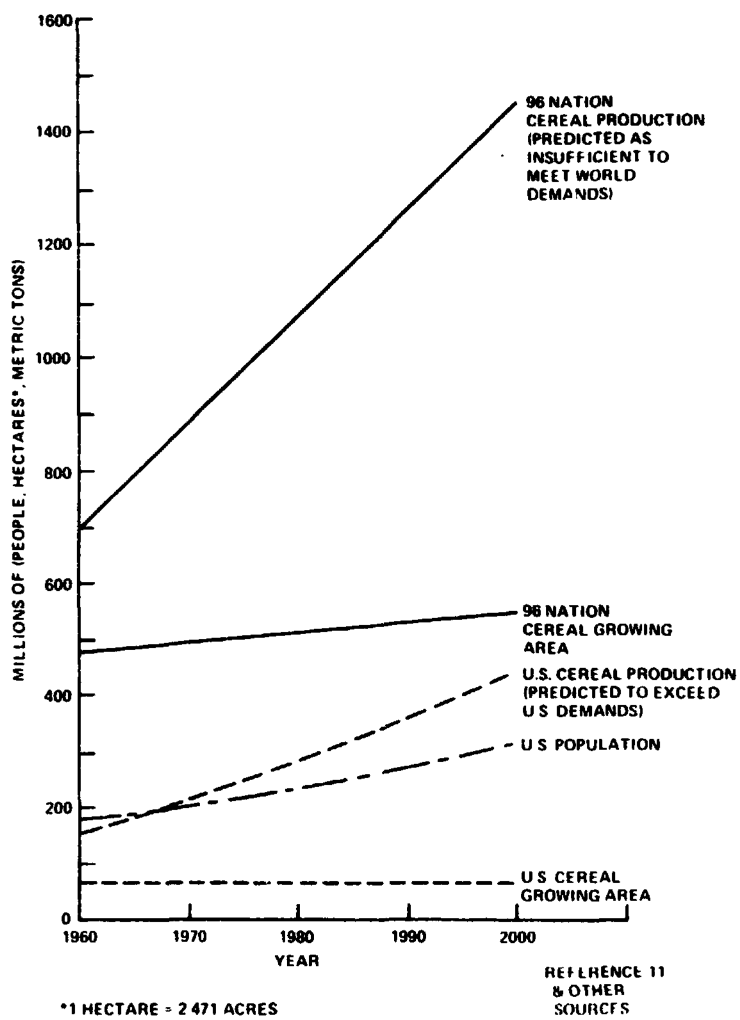


Figure 9. -- Land use demand.

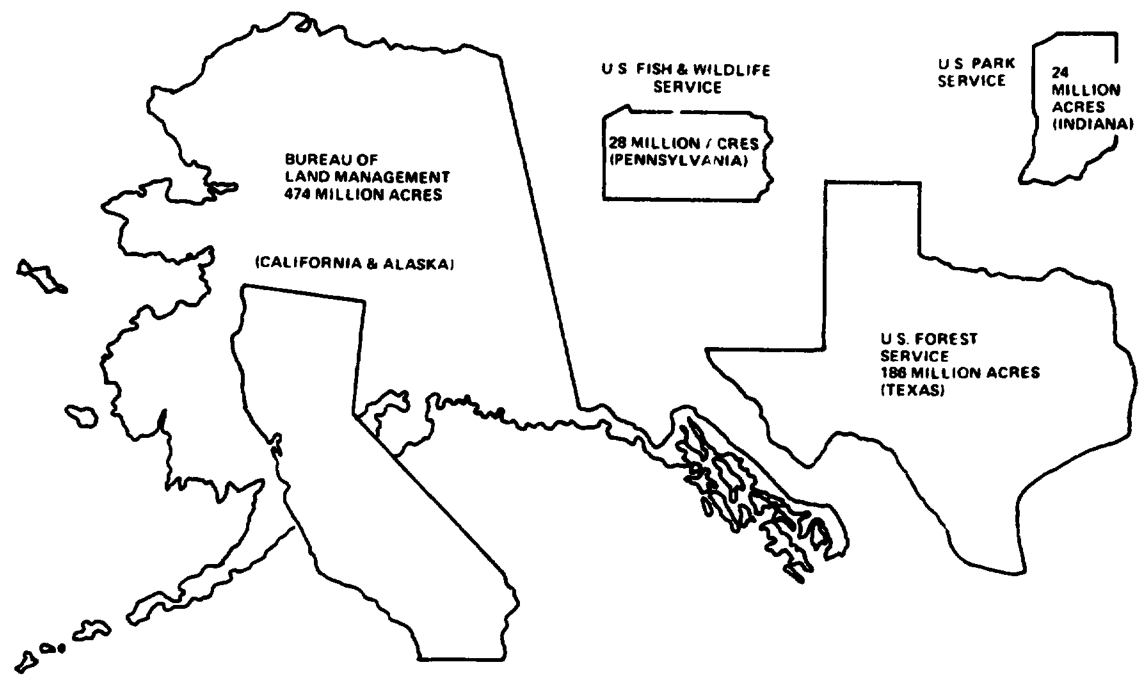


Figure 10.– Jurisdictional area equivalent sizes.

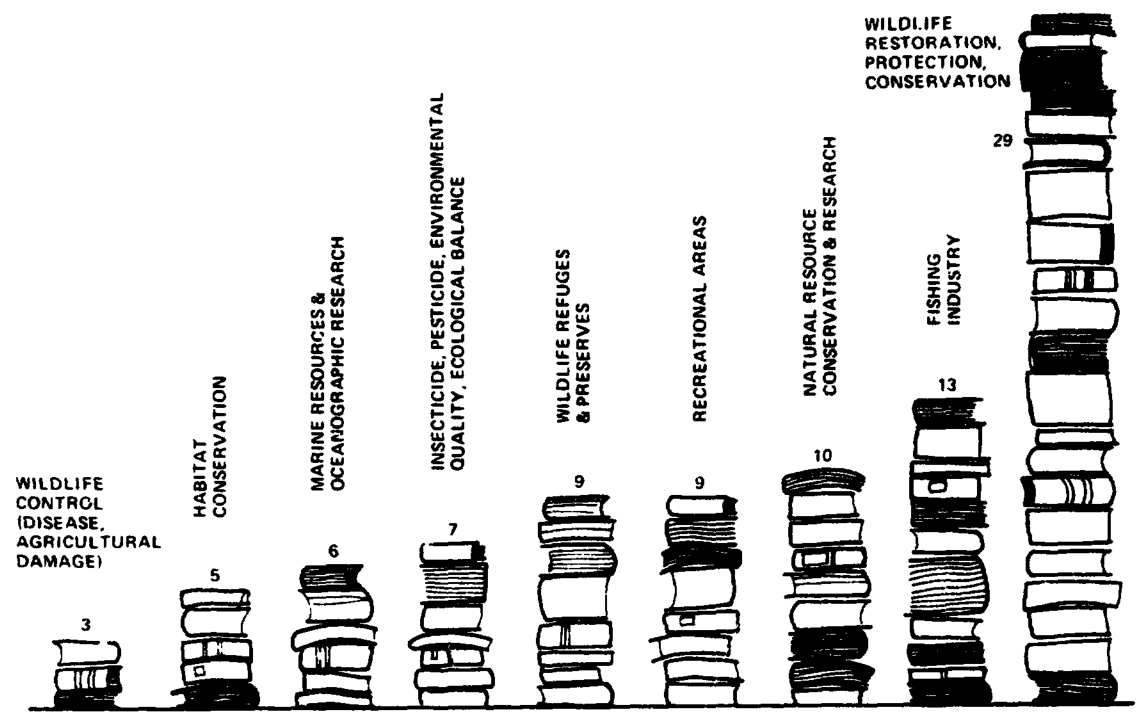


Figure 11.– Selected federal laws.

NUMBER OF SIGNING NATIONS

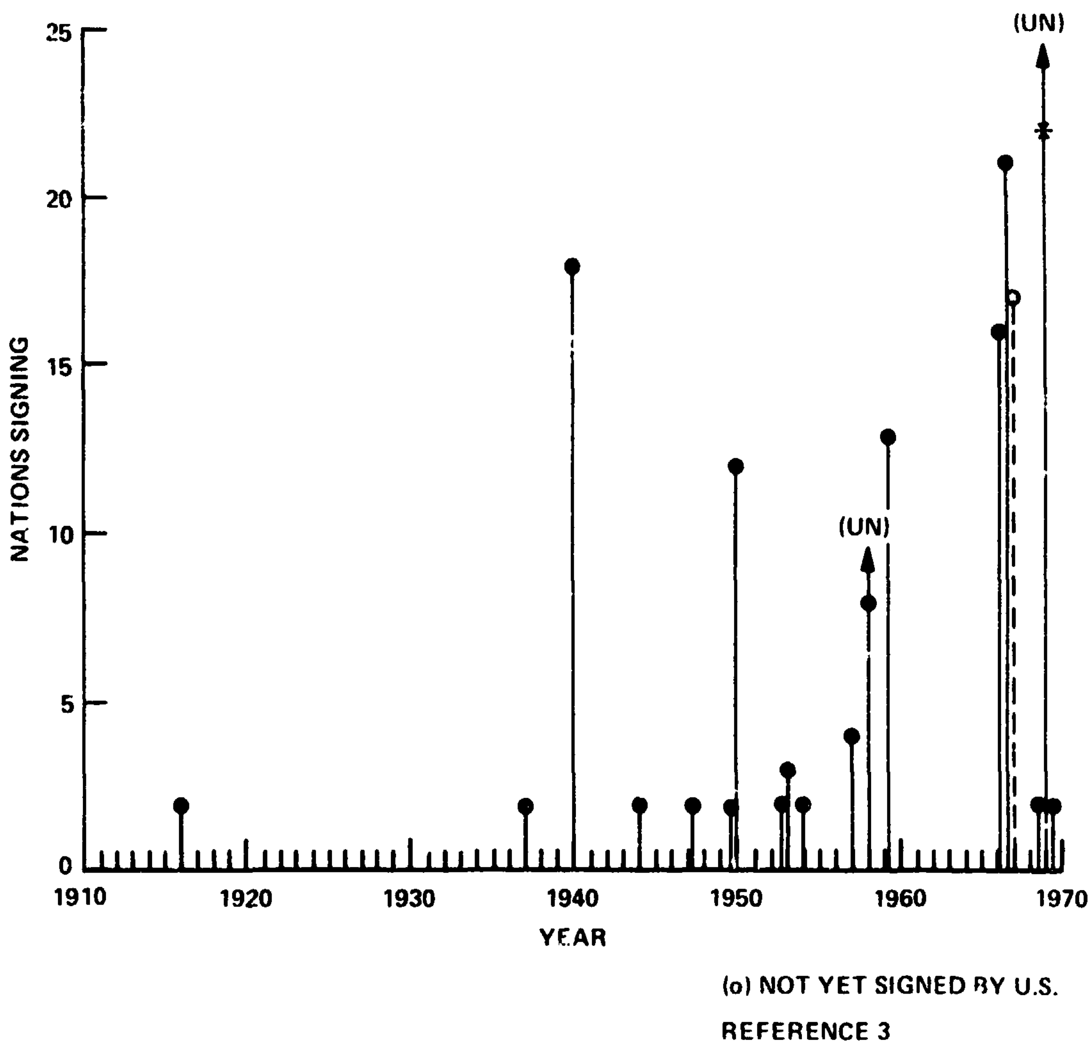


Figure 12.- International wildlife agreements.

(P.L. 92-522), and Lacey Act (18 U.S.C. 42-44). The government agency responsible for identifying and monitoring these threatened species is the Department of the Interior. The Secretary of the Interior is directed by law to seek the council of specialists and agencies with expertise on the subject. The Secretary shall "seek the advice and recommendations of interested persons and organizations . . ."

The Endangered Species Office of the Department of the Interior specifically asks other government agencies to make contributions to help them fulfill their responsibilities. At this time, steps are being taken to coordinate all agencies in an effort to develop a general recovery plan for endangered species (ref. 14). The expertise and technology of NASA applies to some of the needs within the Office of Endangered Species. Habitat assessment from remote sensing satellites and aircraft is the only way that environments can be assessed without disturbing the animals that are being protected. Radio monitoring is the only way to define the exact home range and migratory routes for many animals. These data can then be used to determine where the habitat studies should be made. In many cases, the animals selected for the first studies to be conducted by this program are closely related in size, physiology, and/or habitat to some of the endangered species. Once the ground work has been laid by this early work, the more sensitive species can then be monitored to quickly gather the hard data needed as a base for rational management.

Related Technology and Applications

Wildlife monitoring programs not only can take advantage of aerospace and other technologies, they can also produce valuable data and technology applicable to other fields.

The increasing need for wildlife management has fortuitously been paralleled by advances in communications, electronics, and remote sensing – primarily in the aerospace industry. The unique surveillance capabilities offered by satellite and aircraft systems and the flexibility afforded by microelectronics could be used to great advantage. Most probably, meaningful wildlife monitoring could not be performed adequately without the spaceborne capability of instantaneous and synoptic coverage, or without the possibility of airborne film inventory records, or without the electronic instrumentation small enough to be attached to a single migrating animal. The ability to transmit, relay, receive, record, and interpret large quantities of data automatically makes modern communications and data-handling technology invaluable.

In the same way that wildlife monitoring programs can take advantage of aerospace technology spin-off, there is a strong potential for applying techniques specifically designed for wildlife monitoring to other fields. The overall approach of monitoring ground stations and processing the data centrally is much the same as that required for meteorological data, forest-fire monitoring, agricultural pest control, water management, pollution monitoring, iceberg surveillance, air and ground traffic control, railroad and truck location, patrol car location, etc. The habitat and environment data derived in a wildlife monitoring program could be useful in a variety of land use applications, such as planning highways, urban a, recreation and wilderness areas, powerlines, pipelines, fences, refuges and preserves, agricultural areas, powerplant sites, mines, waste disposal areas, reservoir locations, etc. Technological advances in the areas of instrumentation, communications, and data handling and processing might yield benefits in medicine, disaster warning and assessment, navigation, underwater propulsion, or crime prevention. Some of the possible applications and potential users are shown in figure 13.

PROGRAM STATUS

This section describes existing programs and current hardware state of the art.

On-Going Programs

Funded NASA programs cover many disciplines in wildlife research, including both marine and terrestrial ecological efforts. The approaches vary from remote sensing to intimate interfacing with the animal. Some of these tasks are summarized in figure 14.

Early studies included efforts to track marine and land animals and birds. One such investigation using the Nimbus III satellite tracked an elk over the National Elk Refuge adjacent to Teton National Park in Wyoming. Nimbus III was further used to monitor wildlife during a "hibernation" study in which various parameters of a bear den near the Yellowstone wilderness were monitored through a platform that relayed the data to GSFC via Nimbus III. These studes with Drs. Frank and John Craighead of Wyoming and Montana research organizations proved that investigators could monitor wildlife location and several physical parameters without interfering with the normal behavior of the animal.

Other NASA exploratory efforts by Dr. Archie Carr from the University of Florida (Gainesville) and Howard Baldwin of Tuscon, Arizona, have included design and field testing of marine turtle tracking hardware in the Caribbean waters where these animals are important economically. Another task carried out by Dr. Stuart McKay of Boston University was concerned with radio tracking the far-ranging marine albatross. In addition, a design and test program was built by Drs. Gary Lord, Al Hart, and Bill Aker of the University of Washington, and Howard Baldwin, around the concept of using satellite communications links to relay fisheries data from the remote and hostile waters of the Bristol Bay to the Alaska Department of Fish and Game (ADF&G).

On a nonfunded basis, several tasks are in the process of being approved to use the Nimbus F satellite to be launched in 1974. These include tracking of bears, grazers, and birds. Investigators are required to provide the funding for these efforts and to develop their own hardware. These efforts are set aside from the program as proposed in this report, but it should be possible to use the results as input to the program.

The current Gray Whale Behavior task is a sophisticated combination of various technologies as developed by Mr. Robert Goodman of the Franklin Institute Research Laboratories with the biological sciences as directed by Dr. Kenneth Norris at the University of California, Santa Cruz. The

POSSIBLE APPLICATIONS

WILDLIFE MONITORING DISCIPLINE/PRODUCT	METEOROLOGY	POLLUTION MON	HABITAT MON	DISASTER	RESOURCE SURVEY	AGRICULTURE	FORESTRY	RECREATION PLANNING	URBAN PLANNING	HIGHWAY PLANNING	MINING LOCATION	WASTE MANAGEMENT	POWER PLANT SITE	COMMUNICATIONS IND	LAW ENFORCEMENT	MEDICINE	RESERVOIR SITE
BIOLOGICAL SENSORS		●				●	●						●			●	
ENVIRONMENT SENSORS	●	●	●	●		●	●		●			●	●				
REMOTE SENSORS	●	●	●	●	●	●	●	●	●	●	●	●	●		●		●
ENVIRONMENTAL MODELS	●	●	●	●		●	●	●	●			●	●				●
BIOLOGICAL MODELS		●	●		●	●	●	●				●	●			●	
AIRCRAFT SURV TECHNIQ	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
DATA INTERP/PATTERN REC	●	●	●		●	●	●	●		●	●	●	●				●
MICROELECTRONICS															●	●	●
TRANSMITTER RECEIVER	●	●	●		●	●	●							●	●		
POWER SUPPLY	●	●	●	●	●	●	●							●	●	●	
ANTENNAS	●	●	●		●	●	●							●	●		
DATA HANDLING	●	●	●		●	●	●							●	●		
DATA RELAY(SAT,A'C)	●	●	●	●	●	●	●							●	●		
PROGRAM MANAGEMENT	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●
OUTPUT DATA (RESULTS)	●	●	●	●	●	●	●	●	●	●	●	●	●			●	●

POSSIBLE USERS

WILDLIFE MONITORING DISCIPLINE/PRODUCT	AEC	USDA	FOREST SERVICE	COUNCIL ON ENVIRN QUAL	COM DISEASE CENTER	FAA	HEW	DEPT OF INTERIOR	BUREAU SP FISH & WILDLIFE	NOAA	PUBLIC HEALTH SERVICE	STATE DEPT	USAF	USN	COAST GUARD	CORPS OF ENGINEERS	EPA	STATE GOVERNMENT	LOCAL GOVERNMENT
BIOLOGICAL SENSORS		●		●	●		●	●	●	●	●			●			●	●	
ENVIRONMENT SENSORS	●	●	●	●	●	●		●	●	●	●		●	●	●		●	●	●
REMOTE SENSORS	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●
ENVIRONMENTAL MODELS	●	●	●	●		●		●	●	●	●		●	●	●	●	●	●	●
BIOLOGICAL MODELS	●	●	●	●	●	●		●	●	●	●			●		●	●	●	
AIRCRAFT SURV TECHNIQ	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
DATA INTERP/PATTERN REC	●	●	●	●	●	●	●	●	●	●	●			●		●	●	●	●
MICROELECTRONICS					●	●		●	●	●		●	●	●	●	●	●	●	
TRANSMITTER RECEIVER		●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	
POWER SUPPLY	●	●	●	●	●	●		●	●				●	●	●			●	
ANTENNAS	●	●	●	●	●	●		●	●				●	●	●	●		●	●
DATA HANDLING	●	●	●	●	●	●		●	●	●			●	●	●		●	●	●
DATA RELAY(SAT,A'C)	●	●	●	●	●	●		●	●	●		●	●	●	●	●	●		
PROGRAM MANAGEMENT	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●
OUTPUT DATA (RESULTS)	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●

REFERENCE 3 & OTHER SOU .CES

Figure 13.– Wildlife monitoring application/spin-off.

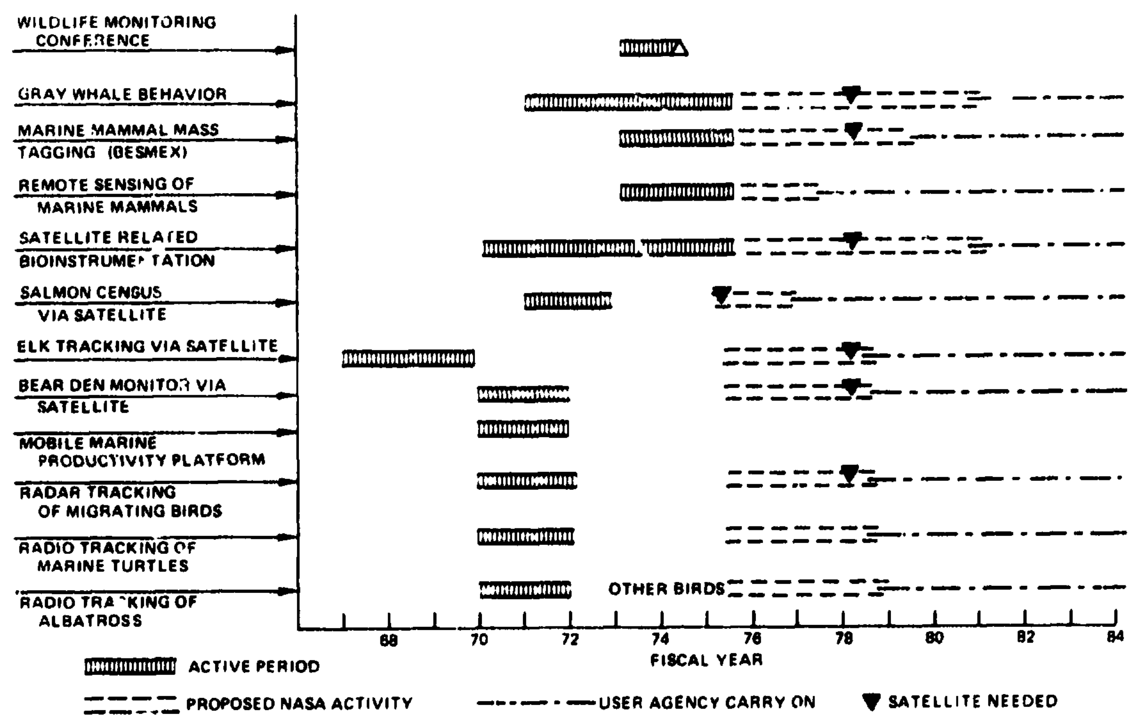


Figure 14.-- NASA wildlife program status.

task is dedicated to radio tracking the migration route of the gray whales from their breeding grounds in Mexican waters to their feeding grounds in the Bering Sea off Alaska. The Mexican government is presently participating in this effort through the work of Dr. Bernardo Villa R. at the University of Mexico.

Dr. G. Carleton Ray and Dr. Douglas Wartzok of Johns Hopkins University are working half-time at Ames Research Center on the proposed Bering Sea Marine Mammal Experiment (BESMEX). This investigation will use radio telemetry and new methods of remote sensing with I.R. imagery to locate and census mammal populations in the Arctic.

Investigators have made good use of NASA tracking stations along the east coast and downrange from Kennedy Space Center to track migrating birds. Such techniques are nondisruptive and use NASA facilities during usual down times.

Dr Roger Gentry, formerly of University of California, Santa Cruz, and now with NOAA/NMFS, a leader in the behavioral and ecological sciences, has been using remote sensing from low- and high-altitude NASA aircraft along with ground truth to study the abundance and movements of California and Stellar sea lions. Once again, the government agencies responsible by law for assessing the animals are greatly interested in the results and how they can be applied on a regular assessment basis. NOAA/NMFS is cooperating with NASA in the assessment of these data.

The only program that has been highly successful in the remote sensing of animal populations from a satellite has been done at the University of Montana. No animals are detectable from satellites at this time. However, specific delineation of the grizzly bear habitat has been defined from ERTS imagery by the Craigheads. Other attempts have been made to define vegetation types and habitats with some success. Intimate knowledge of the animal's needs and good ground truth have been important factors in successfully using the satellite imagery. Also, at the University of Montana, physiological biosensing instruments have been developed. In one on-going NASA-sponsored study, a black bear was instrumented and monitored for deep-body temperature during its winter sleep. The animal was kept in an artificial den and the data relayed outside via telemetry.

The fisheries task, the whale task, the marine mammal mass tagging effort, and a grizzly bear task have been directed toward the development of management models for rational management of these limited resources. Already, the grizzly bear population model has shown positive results as supported by available ground truth. The entire BESMEX task focuses on the production of a rational management model for marine mammals in the Bering Sea.

Other non-NASA research has been carried out by numerous universities, research foundations, and state agencies as well as commercial concerns engaged in the development of wildlife tracking methods. Many states and some government agencies have been radio-tracking important commercial and recreational animal species for many years from ground stations and aircraft. For example, in 1974, the state of Alaska will be instrumenting up to 60 elk in an attempt to determine the structure and movements of the herd

Hardware Technology

Current hardware development is divided into five categories: attachment, biosensors, power packs, transmitters/receivers, and antennas.

Presently, hardware is attached by collars, harnesses, and direct pinning. Collars have been used successfully on several predators and grazers. In one case, a collar was used with Nimbus III and the Interrogation, Recording, and Locating System (IRLS). Harnesses have been developed when collar retention presents problems. The gray whale, the California sea lion, and the albatross have all been successfully harnessed to carry radio and data collection packs. Direct attachment has also been used. Bolts through nonsensitive dorsal fin tissue have held radiotelemetry packages on marine mammals. Sutures held a tracking package on a juvenile gray whale during a successful tracking experiment in 1971. For animals with a leathery skin 1 or 2 inches thick, a package has been built that will use pins to hold the baseplate of the radiotelemeter. Various adhesives and leg bands have been tried with moderate success on bird telemeters. Figure 15 is a diagram of a representative whale harness and instrument pack, which illustrates the current technology in that area.

Biosensors for temperature, heart rate, and blood pressure are ready from previous NASA investigations for adaptation to free-roaming animals. Further sensors in the testing state will be ready in the near future. In addition, ground stations for gathering biological data have also been successful.

Power supplies have long remained a weight problem and investigators have used whatever was best for their purpose at the time. Collars with solar cells have been used successfully on California cougars and other animals. Recharging systems using solar cells on animal collars and charged loops in close proximity to implanted biosensors have proven successful in laboratory tests.

Transmitters for use on animals have varied widely in their range and accuracy. Investigators report a range anywhere from a few miles to 2700 miles, depending on atmospheric, power supply, and antenna conditions. Most investigators have achieved between 15 and 40 miles in tracking with present systems and frequency assignments. An outstanding exception was an albatross that was tracked over a 2700 mile range. Many investigators have used designs from the Bioinstrumentation Advisory Council of t e American Institute of Biological Sciences as a basis for the hardware fabrication.

Antennas vary widely in their application, depending on the habitat, behavior, and size of the animal, and the transmission range required. Examples are banjo strings on birds, modified Yagi antenna arrangements on large grazers, and loaded dipoles.

CORRELATION OF OBJECTIVES AND THE PLAN

The final objective of this program is to realize the benefits from use of aerospace systems in wildlife monitoring by user agencies. Some of these previously listed benefits include:

- Conservation, restoration, and protection of endangered species
- Maximization of commercial and recreational uses

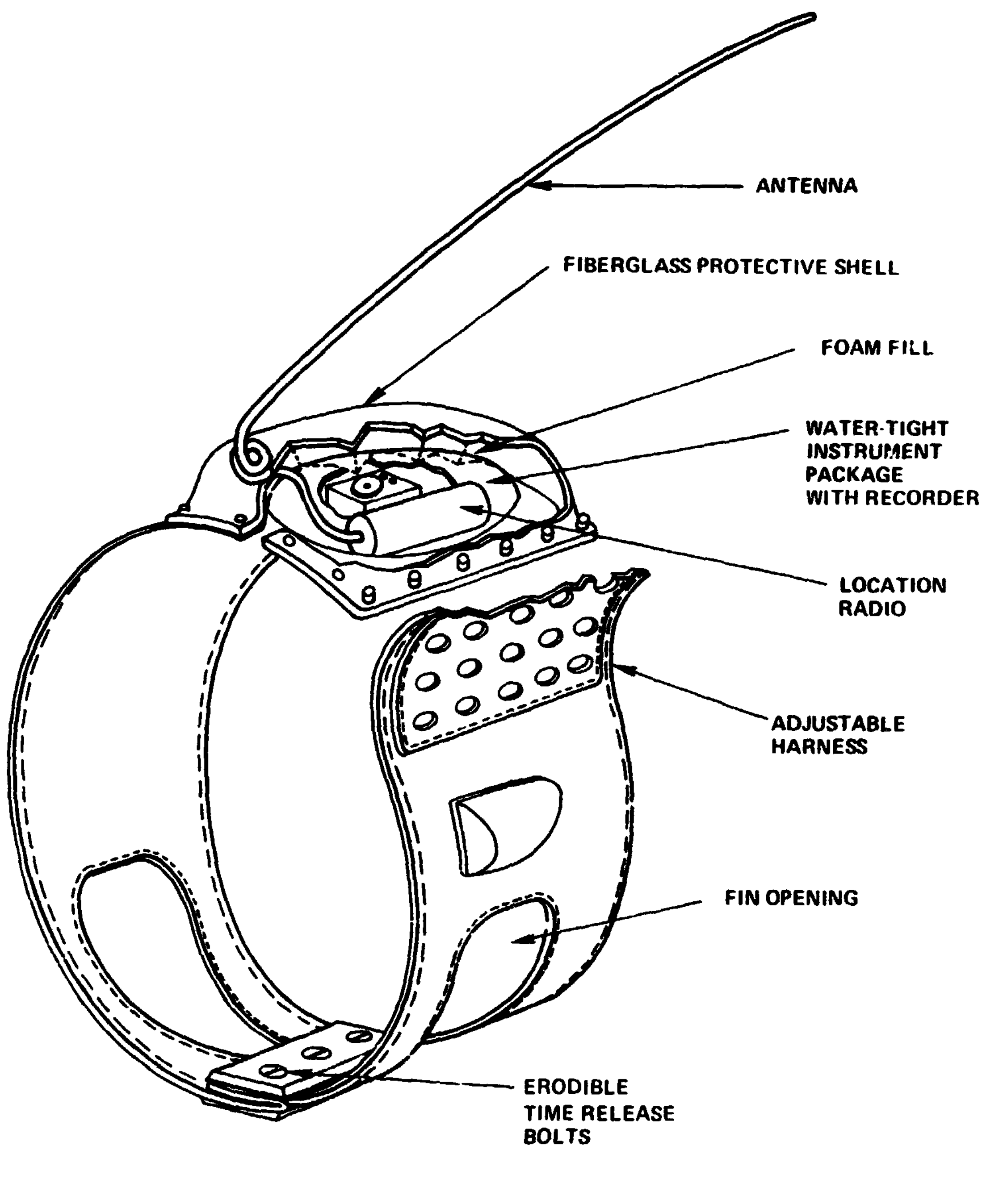


Figure 15.– Typical whale harness.

- Control of disease and damage to agriculture and animals
- Prevention of dangerous interactions with man, and
- Use of the animals as indicators and sentinels of changes in our environment

To realize these benefits, the following information must be obtained:

- Animal census and continuous check on population vigor
- Paths, speed, and direction of movement patterns during the animals' life cycle
- Characterization of the animal's ranges
- Physiological baselines and changes related to health, and
- Behavior in relation to changing habitat

The link between the objectives and the information gathering will be effected in a systematic program.

The specific question of how such information will be used to meet the objectives must be addressed. The information is assembled quantitatively into dynamic predictive models of the type shown in figure 2. The model shown is general and applies to all the species selected for investigation in this program. Each particular study has a model specific to the wildlife species being investigated.

In the model in figure 2, the lines that connect the various circles represent transfer functions involving the transfer of matter and energy with certain efficiencies and entropy changes. The wildlife program is concerned particularly with the large and small predators and grazers. The least important information will therefore concern the lines radiating from these circles. With the transfer equations between the various circles in such a model known, it becomes possible to answer such questions as: What is the maximum rate at which commercial activity can remove large predators (e.g., seals) while the seal population is assumed to remain constant over many years? What will be the environmental result of eliminating a species of small predator? What would be the optimum balance between different species of whales to produce specified commercial by-products while not threatening any one species with extinction? What measures of the environment can be used to predict the total number of migratory commercial fish (e.g., salmon) that will be present in a particular region of the ocean at a particular time?

It should be emphasized that detailed models, centered around the selected wildlife species of this program, are not yet available in quantitative form. The goal of this program is to complete the significant equations in the chosen models.

What can be done now is to state in more qualitative terms the types of information that have the highest priority for the models of the different major species of interest.

Location data can be used to build a data background on individual animal movements that can eventually be incorporated into models to define herd relationship and population dynamics. From a knowledge of location, the user agencies will obtain migration path, speed of animal movement, times spent in each area, and direction of movement in relation to the environment and habitat. Over continuous years of data gathering, the changes in habitat can be compared to location changes to determine if there are significant impacts on animal populations. An example is seen in studies of the marine mammals of the Bering Sea. The location of the animals changes when sea ice moves above the feeding grounds because the habitat changes significantly in relation to the rich stationary feeding grounds. The user agencies need to know how these changes affect the population.

Another change to be monitored is the increased activity by man in the Bering and Chukchi Seas where the walrus and seal populations tend to concentrate. The expanding fisheries industry, the potential sea floor mining industry, and the use of heavy ships to move supplies to the far north as well as the possible removal of oil resources from the Arctic, will all use the same waterways the marine mammals need for their survival. By monitoring changes in ecodynamics and animal location, the responsible agencies will then have information for rational management of marine mammals.

More sophisticated measurements are an extension of a concept that man has used for many years – the concept of "indicator species." For example, since before the turn of the century (even before the 1800's), man has used the canary as an indicator of air quality in mines. Biologists are now aware that other animal species are indicators of the state of the environment. Tissue samples and measurements of pollutants, enzymes, and gas tensions of animals in their native environments indicate the presence of pesticides, herbicides, radioactive elements, and other stress factors. If these substances become concentrated in animal species, their presence may be revealed as changes in their behavior or, as noted by gross census changes, as changes in feeding, reproduction, physiological state, and physical activity as measured by biosensors. The first indications of a contaminated ecosystem might be provided by such measurements. In some cases, such as the marine mammals, this could have dramatic impact on economics because man and some marine mammals use the same species of fish for food. This might indicate that our own food source was in danger.

Another way to monitor pollution or disease that can affect wildlife resources is by use of the "sentinel species" – healthy fish are placed in an environment of water (where they are not found in nature) that must be monitored for quality. Some fish are sensitive to toxic wastes in small amounts. The death or change in behavior of the fish may mean that there is a problem. Other examples of animals that serve as sentinels or indicators would be caribou eating lichens that have concentrated fallout from nuclear testing, sea lions eating fish that have concentrated chemicals from industrialized societies, and free-roaming range animals that could be spreading disease to valuable commercial stock. Instrumentation of animals can detect disease and degradation within ecosystems before they spread.

Measurement of animal physiological functions indicate animal stress and might be used to alert investigators or user agencies that further study is needed to define relationships of the environment, food sources, or human interaction to the species. A specific example would be the occurrence of hoof and mouth disease. Undetected, this disease could wipe out 25 percent of the meat, milk, and other domestic livestock products before it could be controlled. An outbreak in the U.S. might cost $250 million. One method by which the disease can be prevented from spreading is by early detection. Animals strategically located and instrumented for temperature measurement could serve as indicators. The detection of the cyclic temperature changes could indicate when management techniques should be applied. Thus the benefits are directly tied to monitoring animals for their location and behavior as measured by physiological changes.

Behavioral measurement can be used in the management of animal populations. Some information on activity and phonation and feeding events is important in evaluating critical stages of the animals' life cycles. For example, animals such as seals, nesting birds, and even some terrestrial predators are inactive during certain periods of their reproductive cycles. Just how essential this is to making themselves available to the mate or in nurturing and protecting the newborn is not completely understood. As mankind invades the more remote areas where there could be a conflict between the animals and civilization, use decisions will clearly have to be made. Already the Corps of Engineers is generating environmental impact statements. The Bureau of Sport Fisheries and Wildlife is concerned about the feeding activity of the young canvasback ducks that have been disappearing in the last few years. Measurements of the critical needs of animals, which include the home range and activity there, can give these agencies new and important information. A good example of the need to understand phonation in animals is the tuna/porpoise problem. Thousands of porpoise are killed annually during the fishing of tuna. One of NOAA/NMFS's highest priorities is to assess the remaining porpoise populations of the eastern tropical Pacific. During the fishing of tuna, there have been some attempts to frighten away the porpoise with calls of killer whales. If this calling in relation to behavioral and physiological measurements were better understood, techniques could possibly be devised for steering porpoise herds clear of the tuna nets where they are often caught and then drown.

It has been repeatedly stated in conferences and meetings on wildlife monitoring that *location data* must be accompanied by the *environmental, habitat, and census data.* All these data are needed for user agencies to make wildlife management decisions. Such a decision may impact on the number of seals to be harvested from the Priboloff Islands in the Bering Sea, or the number of whales of potential commercial value that are breeding or not breeding, or the number of migrating caribou that are being affected by a transcontinental oil pipeline. Management decisions are needed to determine the number of migratory water fowl that will be hunted each year, and what lands will be available for feeding and stopover for migratory birds. State fish and game agencies will need to evaluate competition between domestic stock and wildlife for natural and planted forage. Many of these decisions can be reached only when the numbers of animals are known and their relationship with the surrounding environment is studied.

The information to be gathered on location, behavior, environment, and physiology as related to behavior will be the basis for management models. These environmental models, as developed between the principal investigators, NASA, and the user agency, will be dedicated to the rational management of animal species of prime concern to the user agencies. In previous years, the solutions to management problems were the best guesses of experts on the basis of inadequate information. These unsatisfactory predictions often resulted in ecological disaster in both marine and terrestrial environments. A few examples are evident in situations such as the removal of all predators from Yellowstone National Park by the U.S. Army, with the result that the limited forage was overgrazed. A similar situation occurred (outlined earlier in figure 4) on the Kaibab Plateau near the turn of the century. The end result was the loss of not only the predator, but a significant part of the vegetation and eventually the grazer population as well. Similar conditions exist today in the fisheries and whaling industries of the world.

At the beginning of this section, it was emphasized that the information about wildlife species was required to construct dynamic predictive models relating that species to the environment and to human intervention (see fig. 2).

A specific example of the types of models to be developed for the five major species selected is presented in figure 16. This figure shows the information needed for a walrus model currently being developed by an interagency team headed by Dr. Carleton Ray, Johns Hopkins University, who is working at the Ames Research Center. Dr. Ray is now developing specific plans and experimental procedures that will enable him over the next few years to obtain the information needed to turn the model into a quantitative predictive tool. Similar procedures will be developed for the other four selected species.

Note that the protocols themselves must be flexible because we do not yet know what the successive funding will be as the program develops, nor do we know which particular types of animal hardware will perform efficiently when attached to animals. In both cases, the early parts of the plans and procedures will be exploratory. The later, more sophisticated investigations, leading to the completion of the predictive model and to its availability as a management tool, will be based on the results of these exploratory activities.

PROGRAM IMPLEMENTATION PLAN

This section describes the process used to select animal species for initial investigation and explains how the monitoring tasks evolve to new species. In subsequent paragraphs, it lists the data to be collected, the techniques of collecting the data, and the technological developments needed as the program grows.

Animal Selection

Several NASA-sponsored studies have included selections of animals that would be the best choices for monitoring. Although these studies have been initiated in several different places for different purposes, the selections do not differ widely.

At the Wildlife Monitoring Conference held at Ames Research Center in the spring of 1973, the user agencies listed their needs and choices. Later, at the Santa Cruz Conference, these needs were prioritized according to the following criteria:

- Animals of special interest to the greatest number of federal, state, and nongovernmental groups;

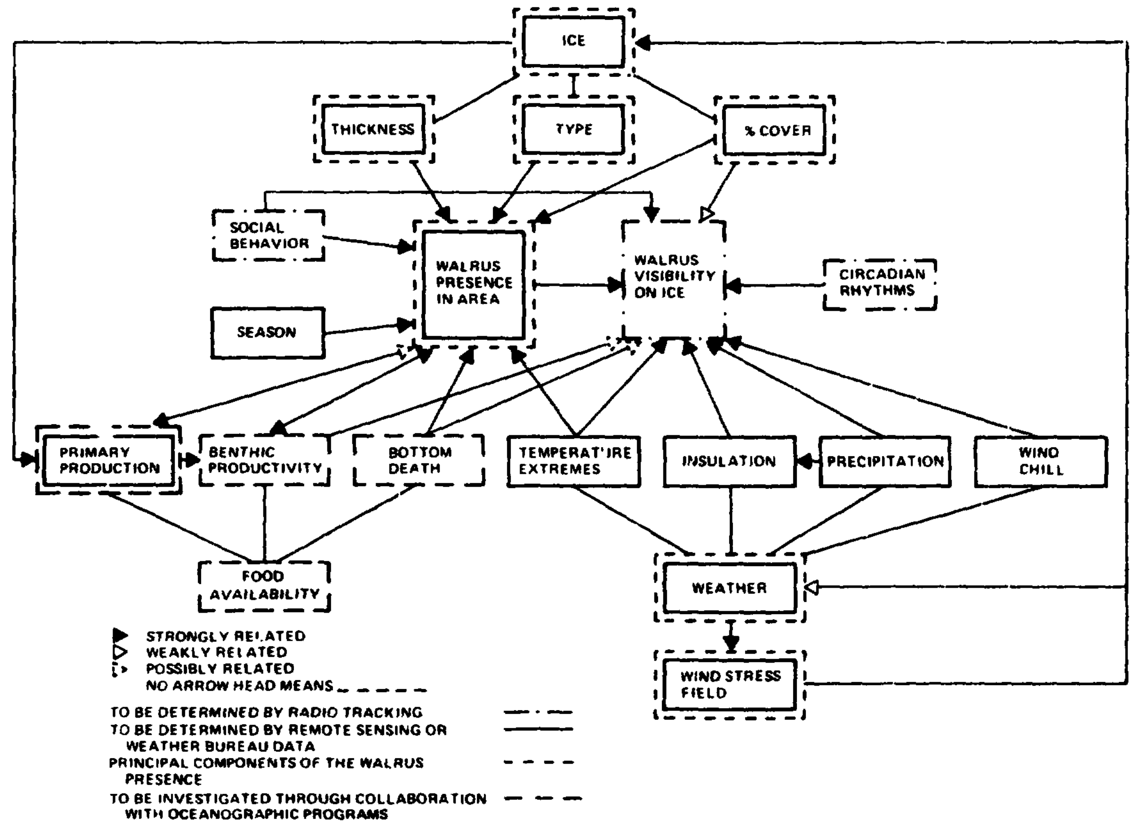


Figure 16.– Heuristic model of walrus ecodynamics: interrelationships between ice dynamics, weather, productivity, and walrus presence.

- Those animals with relationships to man which require urgent study, i.e., disease vectors and other hazardous forms;
- Those animals that are endangered, commercially valuable, or considered to have social or ecological impact;
- Likelihood of developing a practical monitoring system in the near : ure;
- Feasibility of studying the animal in the field.

During the selection process, hundreds of animals were considered. These were divided into 16 groups of animals and assigned 8 levels of priority.

To limit the initial animal monitoring program to manageable proportions, the Santa Cruz selections are further refined in this plan. NASA has gathered significant experience in the technology of wildlife monitoring over the past 10 years with marine, terrestrial, and flying animals. On the basis of this experience, the Santa Cruz selections were therefore reevaluated on the basis of feasibility, experience, and public response. First, a number of field investigations have already shown that different degrees of feasibility must be considered Logistics and operational support must be evaluated. The health and safety of the investigators must be considered. Second a review of past activities in the field has identified the levels of experience to be achieved in animal handling, electronic problem solving, and operational support under inclement conditions. Last, public response can bring either a positive or negative pressure to bear on investigators and public officials alike and hence must be considered. Therefore, these three additional categories are used as selection criteria, with the end objective of ensuring successful demonstrations of the value of aerospace technology. To ensure program control and consolidation of efforts, five species were selected as potential demonstrations: cattle, gray whale, walrus, dog, and waterfowl. These species cover a range of the animal kingdom and represent each main area of the user agencies interests.

As indicated in figure 17, some of the chosen species are domesticated, but they still share many characteristics with wild animals. Cattle, as an example, use the same habitat as wild grazers and often have the same needs. In some cases, they are direct competitors on the open range. Cattle, subjects of extensive study over many years, offer the convenience of easier control, access to a large number of w 'l-qualified professionals who are experienced with their behavior and physiology, the use of a number of well-equipped agricultural schools, and provide further opportunity to do complete biological studies without the opposition of sensitive conservation groups. Handling techniques, harnesses or collars, and bioinstrumentation developed on cattle can be directly applied to a number of wild grazers. Figure 18 shows the flow of technology from a demonstration project to wild animal groups of interest to the user agencies.

These selections will enable NASA to carry out many of the demonstrations under closely controlled conditions. As techniques are proven, the other animals for field applications will be selected by the user agencies. The system evolution (fig. 19) suggests the flow from species to species based on the stated user needs and the ease of technology adaptation, thereby maximizing the probability of successful implementation and data return.

ANIMAL			PRIORITY RATING				
			SANTA CRUZ REPORT	FEASIBILITY	EXPERIENCE	PUBLIC RESPONSE	ARC RECOM
PREDATORS							
	CANINE	DOG	1	●	●	◑	4
		WOLF	1	◔	◔	◔	
		COYOTE	1	◑	◑	◑	
	FELINE	COUGAR	[illegible]	◔	◔	◔	
		LYNX	1	○	○	◔	
	BEARS	POLAR	1	○	◔	◑	
		GRIZZLY	1	●	●	◑	
		BLACK	1	●	◑	◑	
GRAZERS		CATTLE	2	●	●	●	1
		DEER	2	◑	◑	○	
		ELK	2	◑	◑	○	
		MOOSE	2	◔	○	◔	
		ANTELOPE	2	◔	◔	◔	
		CARIBOU	2	○	◔	○	
MARINE MAMMALS		YOUNG WHALE	1	●	●	◑	2
		ADULT WHALE	3	○	○	◑	
		PORPOISE	1	●	◑	◔	
		SEAL, SEA LION	4	●	◑	●	
		WALRUS	4	●	◑	◑	3
SEA TURTLE			2	●	◑	◑	
FISH		BILL FISH	2	◔	○	●	
		SCHOOLING FISH	5	◔	◔	●	
		SHELL FISH	6	◔	◔	●	
BIRDS		WATERFOWL	1	◑	◑	●	5
		BIRDS OF PREY	2	◔	◔	○	
		PASSERINES	6	○	◔	◔	
RODENTS			1	◔	○	◑	
INSECTS			7	○	○	●	

● EXCELLENT ◑ GOOD ◔ FAIR ○ POOR

Figure 17.– Animal selection rationale.

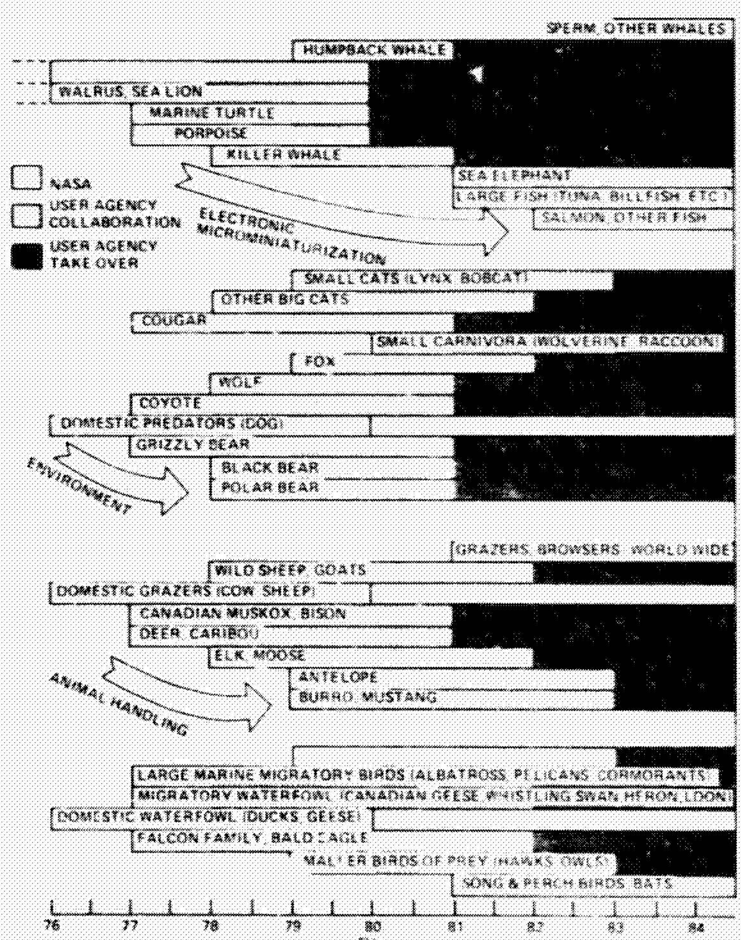


Figure 18.– Wildlife Monitoring Program growth.

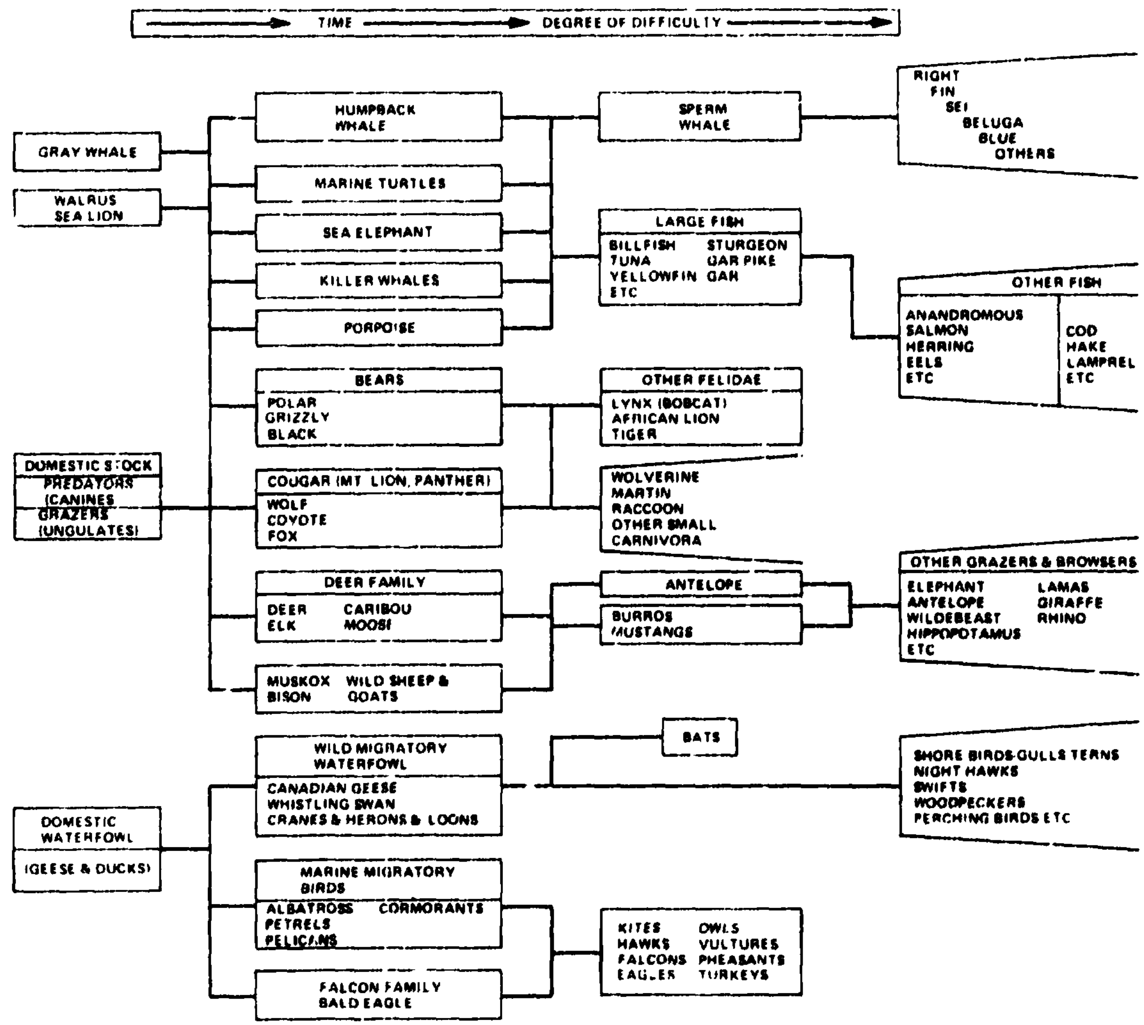


Figure 19. -- Systems evolution of Wildlife Monitoring Program based on needs, present technology and ease of technology interface.

Data Collectio

The data-collection tasks that must be undertaken to satisfy the wildlife monitoring objectives and to create dynamic models are described in this section. The type and extent of the data collected will expand as the wildlife monitoring program unfolds. Initially, the data-collection tasks focus on animal location, then on censusing and habitat. As the technological capabilities increase, more effort will be devoted to behavioral and physiological data. At the same time, more and more species will be monitored over wider geographical areas as the user agencies take over management monitoring operations.

Several user agencies have impressed upon NASA their needs for synoptic views of the environment and for censusing animal populations. Environmental information is already being collected and processed for users via the ERTS system. Additional data are being gathered by high-altitude remote sensing aircraft. A combination of these data has already proved valuable in assessing the habitats of wilderness regions. However, the ERTS system has been unable to resolve individual animals even when they are congregated in large herds nor was it planned to be. Preliminary studies have demonstrated the value of using high-altitude aircraft for census work on terrestrial and amphibious animals. If several animals of a species can be located by radiotelemetry, remote sensing aircraft can be directed to appropriate areas to assess total population.

The way in which data for the five major study groups will be gathered for management models (as outlined in fig. 5) is explained in the following paragraphs.

Grazers – The location of a grazer is very important. From this information, other steps of the investigation are initiated. Census, habitat, meteorological and geophysical studies can be defined in area and scope when definite locations are known. In grazers, there will be heavy emphasis on vegetation, hydrology, atmosphere, and census data. For monitoring disease and for defining behavior, there is emphasis on bioinstrumentation. The bioinstrumentation effort will be emphasized in the grazers because they offer a platform for development for other species that are harder to handle.

Whale – Census information is of prime importance in the study of whales. To achieve this, location techniques will be of great importance. Once the location technology allows migratory paths and routes to be defined, census studies will be more meaningful. Behavior studies will be necessary to complete the census and migration studies. Physiological measurements will be limited to those that can enhance the behavior and migration/census studies. Water quality and vegetation (planktonic) measurements will be made in a limited manner along with solar flux and magnetic field measurements. The latter two will be examined for possible use as migratory cues and orientation factors in navigation.

For pinnipeds (seal family), the priority of the user agency is census data, which cannot be gathered without knowledge of the location of the animals; therefore, the emphasis will be on these two areas. Behavior and physiological measurements will be secondary. Limited efforts in habitat definition and meteorology are included where they help define migratory patterns and censusing, and hence contribute significantly to dynamic population models.

Predators – Although location is important in monitoring predators, exactly what the predator is doing at that location interests the user agencies. Therefore, location is an area of medium effort, but heavy emphasis will be placed on those behavioral and physiological measurements that tell the user agency how the predator is interacting with the environment. Habitat definition will be important, with emphasis on vegetation studies and a small effort in hydrological relationships. Meteorological and geophysical studies will be included where they relate to the area of prime importance.

Birds – Census and location are of prime importance to the user agency in monitoring waterfowl. These areas will constitute major efforts. To understand the environmental influences on population, behavior, and migration, there must be a strong emphasis on habitat studies, which will include vegetation and water. Physiological studies are currently almost completely eliminated by weight constraints. The location of waterfowl is probably influenced by meteorological factors. The definition of hydrological and atmospheric phenomena is consequently important in the management of the birds. Figure 20 summarizes the information priorities for each of the selected initial species.

Many institutions have been determining what measurements would be meaningful to physiologists and behaviorists. At the NASA-sponsored Wildlife Monitoring Conferences, biologists, engineers, and user agencies carefully selected those physiological parameters that would be important in constructing wildlife models. In physiological and behavioral measurements, three categories were identified and recommended for development:

Category I (applicable now)

- Temperature
- Heart rate
- Blood pressure
- Simple physical activity
- Orientation

Category II (near future, 2 plus years)

- EEG
- EKG
- Blood flow
- Heart load
- Selective activity
- Phonation
- Feeding events

Category III (future, 4 plus years)

- PH
- Gas tensions

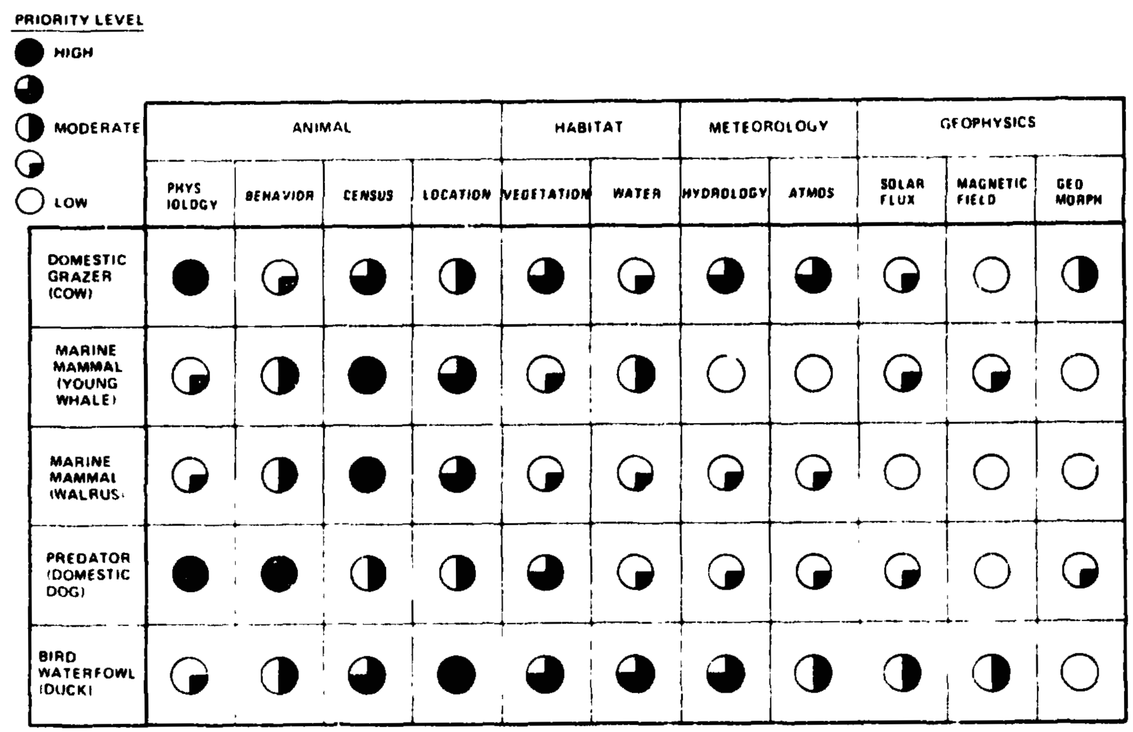


Figure 20.– Wildlife monitoring data collection tasks.

Enzymes
Pollutant absorption
Voiding
Pregnancy
Complete activity
Food/water intake

Some of the systems already developed provide measurements of cardiovascular functions and activity. These data give some indication of the state of the animals' health and the degree of stress to which they are subjected.

Role of System Elements

The diversity of wildlife monitoring data requirements precludes the use of any single optimum data-collection platform or sensor system. Applicable data-collection techniques include everything from animal-mounted instruments to remote sensors in geosynchronous orbit. Data needs range from specific animal physiological characteristics to general environmental factors. Surveillance schedules vary from once every few weeks to continuous observation. The form of the data can also vary significantly, depending on the animal, its size, behavior, location, habitat, and migration patterns.

The two primary aspects of data handling are collection and management. Data can be collected directly, as with animal-mounted sensors, or indirectly with field stations, satellites, or aircraft. Once obtained, the data must be transferred, processed, and distributed to the user. The best data-handling system is one that uses the advantages of each individual technique. Some advantages and disadvantages of the various approaches are considered in the following paragraphs.

Animal-mounted sensors are indispensable for obtaining physiological data (i.e., heart rate, temperature, and other bodily functions). Such instruments can also be used to collect data on animal behavior, or they can be used, in conjunction with other equipment, to locate animals. Animal-mounted sensors can also be used to monitor environmental conditions or habitat. But making environmental measurements from an animal-mounted platform with unknown location, orientation, and motion may involve too many ambiguities to be of use.

Remotely located field stations, relaying their information to a central processor, would be especially appropriate for environmental monitoring. They might also be used to observe animal activities or to relay data on animal conditions and location. Although the in-situ data received from a field station may be impossible to collect any other way, the area covered by any one station is relatively small. Hence, the number of stations required could be very high.

Field parties would be required to install animal-mounted sensors and to install and maintain remote stations. Field parties can also make on-site observations and perform data-collection functions that would be nearly impossible any other way. A field party is restricted in the area it can cover, and although it might demonstrate a unique flexibility, it suffers from a correspondingly high cost. During discussions at the Santa Cruz Conference, for example, marine mammalogists estimated that blue whale studies require one ship per whale. A one-year track of one whale could cost $3.5 million when ship time, crew rotation, and logistics are considered.

Aircraft can cover large areas on a relatively flexible temporal basis. They can be used to collect images of the habitat or, in some cases, animals. It is feasible, but less likely, that aircraft or dirigibles could be used to relay telemetered data from animals or ground stations. An aircraft was used in one instance to track an albatross with an installed radio transmitter.

Satellites can cover areas on a global scale, collecting data on environment and habitat and even locating animals through radio tracking. Two types of satellites are of primary interest. The first, in sun-synchronous orbit, encompasses such examples as Nimbus and ERTS. These satellites are in near polar orbit at an altitude of about 1100 km (600 n.mi.). Imaging rates can vary from complete coverage everyday to once every 18 days or more. The second satellite of interest is in geosynchronous orbit, such as ATS. At an altitude of 35,870 km (19,400 n.mi.), the view is nearly hemispherical, but with severe distortion over much of the earth's surface. Generally speaking, animals can be located more accurately from the lower satellites. (Location accuracy capabilities vary from about one to several tens of kilometers.) The continuous coverage capability of a geosynchronous satellite is invaluable in monitoring field sensors and in relaying data to a processing point. All the above system elements are shown in figure 21.

The various performance parameters that might be used to evaluate the most appropriate role of satellites, aircraft, and ground sensors are listed in figure 22. Specifically, these include continuity in coverage, size of area viewed, image resolution, animal location accuracy, observation schedule, flexibility, and accessibility of the animal. Obviously, no one observation technique is best in all areas of performance. For this reason, and since in most cases no single observation platform can operate independently, more than one technique is required.

Figure 22 summarizes the attributes of the various data-collection platforms. The figure distinguishes between animal-mounted instruments and other gear to emphasize the fact that animal instrumentation is neither a substitute for nor in competition with other modes of data collection, but must be used in conjunction with other data-collection techniques.

Two easily defined monitoring parameters are size of the animal and the extent of its migration. Yearly migration distances indicate how accurately the animal should be located, and animal size is a main factor in determining the resolution needed for imaging. Imaging satisfies the requirement for location but may not always be a practical way to track the animal. Location accuracy requirements may be looser than imaging resolution by several orders of magnitude, thereby making satellites viable alternatives for this task. Figure 23 shows an imaging resolution capability determined roughly by the animal size and a location accuracy as a function of total migration distance. The right-hand edge of the figure shows an estimate of the ground area that would have to be covered each day to stay abreast of an animal with the annual migration habits shown on the left side of the figure. The estimate is based on animal migration habits, speed, etc. There is a great deal of uncertainty in the travel of an animal in any one day, but the area parameter is useful in gauging satellite and aircraft coverage rates.

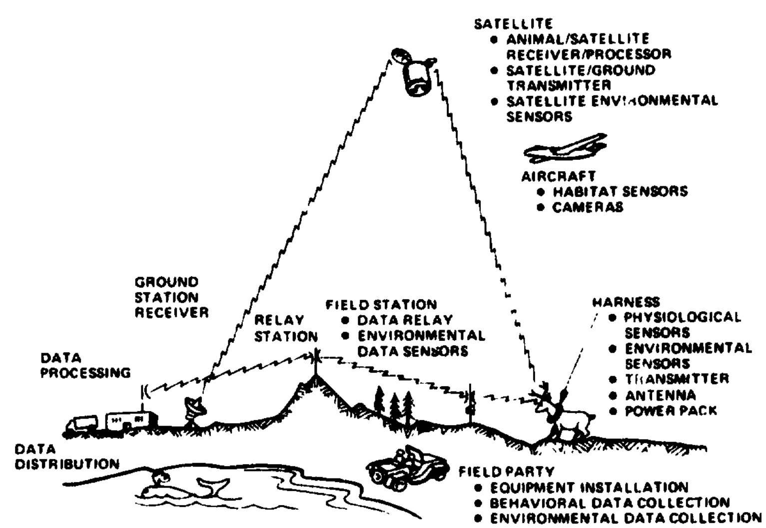


Figure 21.– Wildlife monitoring system schematic.

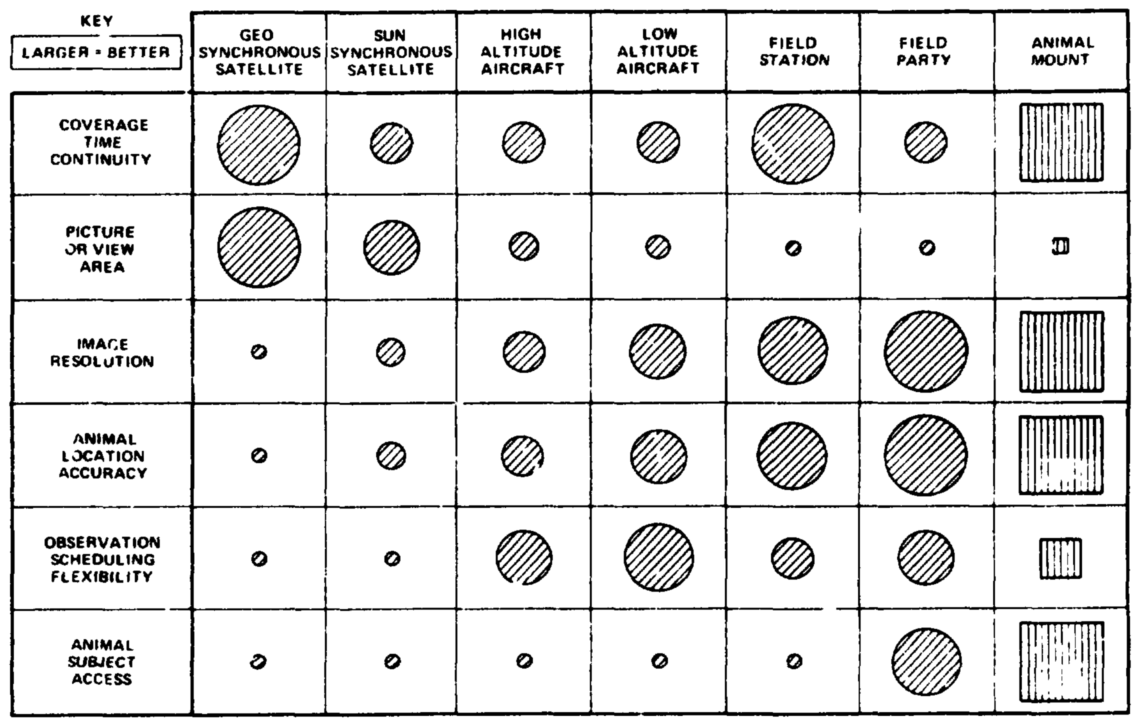


Figure 22.– Wildlife monitoring platform capabilities.

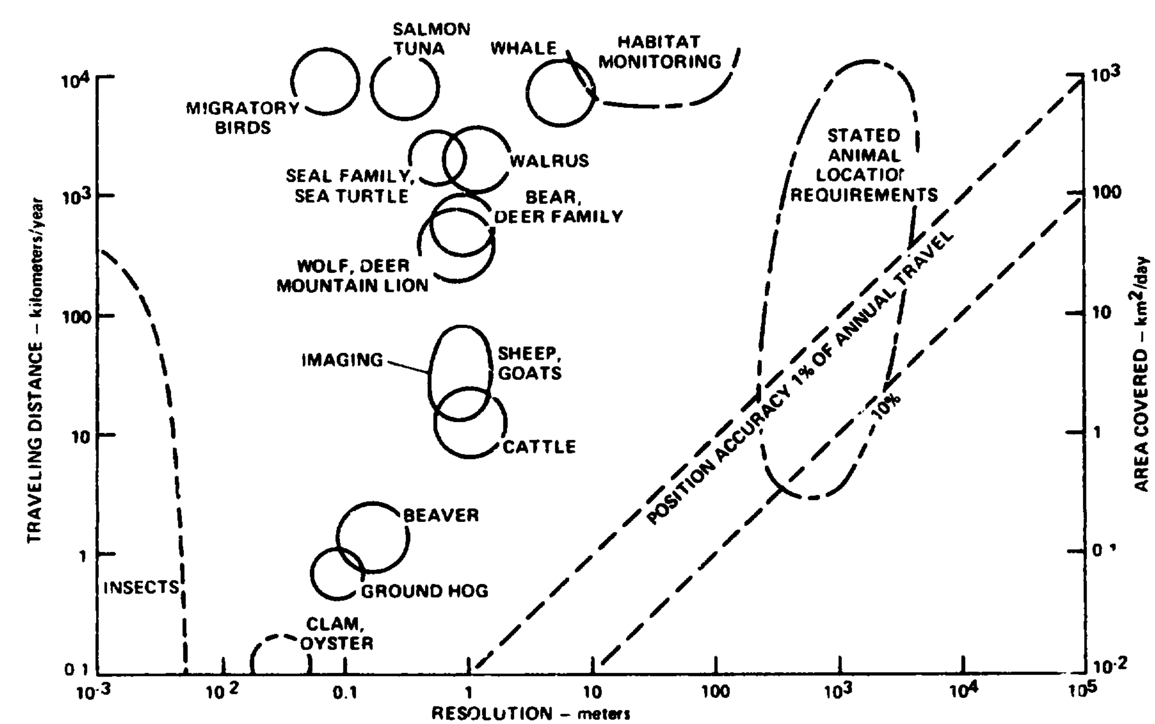


Figure ^3.– Wildlife migration and resolution trends.

The animal migration and resolution requirements shown in figure 23 can be superimposed on a graph of coverage and resolution capability of satellites, aircraft, and ground surveillance methods as in figure 24. With current technology, it is evident that aircraft can meet the imaging resolutions for many animals, and satellites can meet the requirements for locating animals in many cases. Habitat imaging requirements tend to be less severe than animal imaging requirements (typically on the order of 10 to 100 m resolution) and are hence largely satisfied by satellite. A more conclusive reason for using satellites in habitat monitoring, however, is that the total area to be covered may extend far beyond the capability of a limited number of aircraft and could include areas on all parts of the globe. For example, one ERTS picture 100 miles square could cover the entire grizzly bear habitat and then move on to cover part of the whale habitat in the same day.

The appropriate roles of the various data-collection and data-management techniques can be defined more accurately if the individual requirements are addressed specifically. Figure 25 shows the kinds of information desired and the corresponding suitability of the various data collection and management methods. In short, it suggests the following roles for wildlife monitoring data collection:

- Geosynchronous satellite
  - Cloud monitoring
  - Data relay
- Sun-synchronous satellite
  - Habitat monitoring
  - Meteorological data
  - Animal location
  - Hydrology-geomorphology
- High-altitude aircraft
  - Animal location
  - Habitat monitoring
  - Hydrology-geomorphology
- Low-altitude aircraft
  - Animal censusing
- Animal-mounted equipment
  - Animal physiology
  - Location
  - Animal behavior
- Field station
  - Water monitoring
  - Meteorology
  - Environment

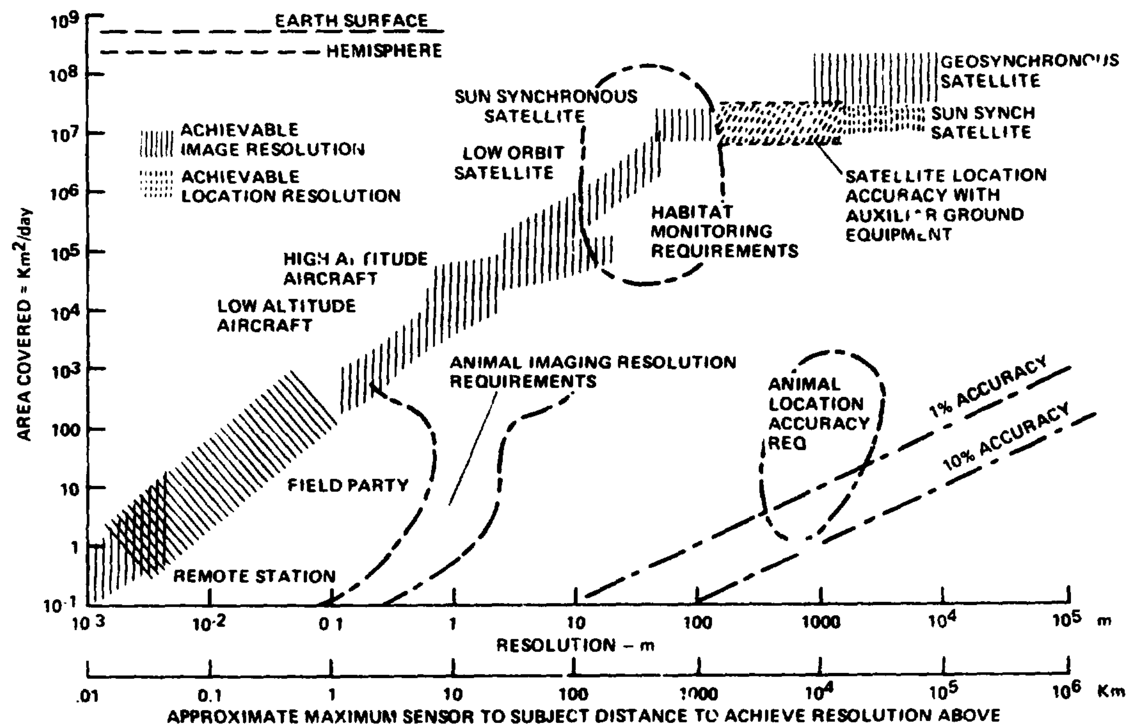


Figure 24.– Platform and sensor resolution and coverage capability.

KEY

	GOOD	FEASIBLE
DATA COLLECT'N	▲	△
DATA RELAY	●	○

INFORMATION			SATELLITE: EARTH (GEO) SYNCHRONOUS, E G ATS	SATELLITE: SUN SYNCHRONOUS, E G ERTS	SATELLITE: LOW ORBIT, E G SKYLAB	AIRCRAFT: HIGH ALTITUDE, E G U-2	AIRCRAFT: LOW ALTITUDE, E G QUEENAIR	ANIMAL MOUNTED EQUIP	FIELD STATION	FIELD PARTY
ANIMAL	PHYSIOLOGY	TEMP HEART ETC	●	○	○			▲	○	
	BEHAVIOR	FEEDING ORIENTATION ETC	●	○	○			▲	○	△
	CENSUSING					△	▲		△	△
	LOCATION		△	▲	▲	▲	△	▲	△	△
HABITAT	VEGETATION	TYPE, CONDITION		▲	▲	▲	△			△
	WATER	WATER LOCATION		▲	▲	▲	△			
		WATER MOVEMENT	●	△ ○	△ ○	△	△		▲	△
		WATER TEMPERATURE	●	△ ○	△ ○	△	△		▲	△
		WATER CHEMISTRY	●	○	○				▲	▲
METEOROLOGY	HYDROLOGY	SURFACE WATER		▲	▲	▲	△			
		RAINFALL	●	△ ○	△ ○				▲	△
		SNOWFALL	●	△ ○	△ ○				▲	△
		SNOW/ICE COVER	△ ○	▲ ○	▲ ○	▲	△		△	△
		SNOW/ICE DEPTH	●	○	○				▲	△
	ATMOSPHERE	WINDS	●	○	○				▲	△
		TEMPERATURE	●	△ ○	△ ○	△		△	▲	△
		HUMIDITY	●	△ ○	△ ○	△		△	▲	△
		PRESSURE	●	○	○			△	▲	△
		CLOUDS	▲	▲	△	△			△	△
GENERAL	GEOMORPHOLOGY			▲	▲	▲	△			△
	SOLAR INTENSITY		●	○	○				▲	△
	NOISE LEVELS		●	○	○			△	▲	△
	MAGNETIC FIELD						△	△		▲

Figure 25.– Wildlife monitoring data handling.

- Field party
  - Animal behavior
  - Environment
  - Install and maintain equipment

The precise role of any one monitoring methodology must ultimately be determined by the species under observation. For example, satellites may be mandatory for tracking wide ranging animals or animals in a hostile environment. On the other hand, satellites may be quite inappropriate for collecting data from a small, accessible or controlled site.

.. typical investigation using aerospace technology will take on a multifaceted approach. Location of the animal could be done with RAMS (Random Access Measurement System) or Omega OPEL (Omega Position Location Experiment) systems. Physiological parameters of the animal will be transmitted from inside the animal to the receiver-transmitter harness or collar and transmitted to the satellite system. In addition, sensors on the harness or collar will feed information about the local environment to the receiver-transmitter and that data will likewise be transmitted to the satellite system Aircraft will also be used for remote sensing of the habitat and sometimes for visual location of the animal. In marine studies, ships will be used for ground truth and habitat studies. At sea, there may be opportunities to use data buoy stations. In census studies or migration studies, the use of platforms such as sonar buoys at specific locations can be used to count and track animals or to pick up and record data transmission as they pass by. Similar stations will be used for those animals in hostile and remote land areas or where migration of the animals may be limited. Tethered balloons were noted in the Santa Cruz study as a way to increase the range of radiotelemetry. It was also pointed out that buoys, ground stations and balloons could be used as environmental data-collection centers. The environmental sensors that would be located on the harnesses, collars, ground stations, buoys, and balloons would gather the following data:

- Vegetation type
- Extent and depth of water
- Wind speed and direction
- Air and water temperatures and other meteorological measurements
- Incident light, its character, intensity, periodicity, and distribution
- Ice and snow distribution

A NASA study has been completed that proposes using many of the above concepts for application to fisheries management. Fish populations can be counted with sonar buoy The collected data are relayed to a shore station that uses a satellite to transfer the information to the user agency for input into their management model. A cost benefit study has been included as part of this task for assessing salmon stocks via satellite for the Alaskan Department of Fish and Game. The relative economic benefits of increasing the accuracy of the population counts were formulated from data on minimum, average, and maximum run sizes over a 10-year period The results show that a reduction in the variance of the run-size estimate by 50 percent would be cost effective if it could be obtained for less than $300 thousand a year. It has been calculated such results are easily attainable at an outlay of $400 thousand and by use of the already existing ATS data relay system. Therefore, in two years the system would become cost effective even with an outlay of $100 thousand per year for operation and maintenance. The present inadequate assessment system using chartered ships and aircraft costs approximately $250 thousand per year and has resulted in a decline from a 50 million fish per year industry at the turn of the century to a present 2 million salmon per year harvest.

NASA presently has two unique radar-tracking capabilities that are suitably placed and instrumented for tracking birds. Although these types of radar can be used for tracking land animals, they are more practical in the area of bird sensing. The NASA surveillance and tracking radars at Wallops Station have already been used for this purpose. These Ka, S, X, and UHF band radars are ideally placed along the eastern migratory bird flyway. The basic research already accomplished indicates that not only location, speed, and direction are determinable, but other factors related to altitude, wing beat rate and continuity, and the question of whether the bird is in long-distance migration are definable. These studies will be expanded by attaching transponders to the birds. Another system that should be explored to determine its capabilities is high-frequency, over-the-horizon radar.

Data-collection tasks and laboratory investigations will be carried out by teams. RFP returns and unsolicited proposals will be evaluated for both biological and technical personnel team strength. NASA personnel will interface with the teams at their level of expertise, i.e., communication, harness structure, or instrumentation. A NASA coordinator will monitor and help structure all activities in a systematic manner during development, testing, and field demonstration. As the project develops, the NASA coordinator will bring the user agency more and more into the operational data-collection phase.

Hardware Research and Development

The development of hardware items is presented in five categories: animal instrumentation, environmental instrumentation, communications, data collection, and data interpretation. The funding requirement in each category is divided into two parts, that which is common to all species, or modular, and that which is peculiar to individual species. Figure 26, which outlines the hardware development effort in dollars versus time, shows a total magnitude of $4.2 million, over half of which is devoted to commonality among many species. The largest single item, at $2 million, is designated for communications and data relay.

Technological commonality is present in all areas. In the actual interface with the animals, the peculiar requirements will require focused attention. The strongest example of commonality occurs in the communications equipment and data relay. Efforts in miniaturization, microminiaturization, and the development of power supplies, circuits of receivers and transmitters, and antennas can be consolidated. The packaging problem is generally peculiar to each species, particularly with birds. Another such example exists in harness and collar development. Commonality is found in materials, attachment and release mechanisms, and in collar expansion during animal growth. However, the

	ANIMAL HARDWARE R & D APPLICATION	(FY) TIME PERIOD OF EFFORT	TECHNOLOGICAL AREA				
			HARNESS, HANDL NG, & BIO-INSTRUMENT	ENVIRON-MENTAL SENSORS & PLATFORMS	COMMUNI-CATIONS EQUIPMENT & DATA RELAY	DATA COLLECTION (AIRCRAFT, FIELD PARTIES ETC.)	DATA INTERPRET-ATION, MODELS & DISTRIBUTION
	COMMON TO ALL SPECIES	76-87 (= CONTINUOUS)	650	170	1200	300	300
EQUIPMENT EFFORTS PECULIAR TO PARTICULAR SPECIES	WHALES WITHOUT DORSAL FIN & TURTLES	76-82	60	10	100	50	50
	WHALES WITH DORSAL FIN & PORPOISE	77-82	40	–	100	–	–
	FISH	81 87	40	10	100	50	50
	LARGE PREDATORS	76-81	50	–	50	50	10
	SMALL PREDATORS	77 83	30	–	50	–	10
	LARGE GRAZERS	76-84	50	–	50	–	10
	SMALL GRAZERS	77 80	30	–	50	–	10
	BIRDS, WATER FOWL	76-84	50	10	300	50	30
	TOTAL		1000	200	2000	500	500

Figure 26. – Wildlife monitoring hardware development effort (in thousands of dollars).

peculiar characteristics of the different environments and the behavior of each species demand a variety of attachment methods. The bioinstrumentation required to define behavioral traits shares a great deal of commonality and, with the mammals, can be applied to a number of species with little specific adaptation.

Data-collection and telemetry systems that can be carried on such species as free-roaming grazers, predators, and migrating birds are available, but there is a great need for miniaturization. Current packages are either too bulky, too heavy, or too short-lived. The primary need at the present time is for equipment with greatly reduced continuous power drain. It is the continuous operational power (as opposed to the RF power) that determines power source size and package lifetime. The immediate goal in animal-mounted telemetry systems is a 50 percent or better power reduction, which could result in a 1-lb package with a 6-month operational life. This 100 $in.^3$ demonstration package would be made compatible with the Nimbus F and would probably require a 12-month hardware development effort headed by Goddard Space Flight Center. Other tasks are in the area of microstrip antenna technology and high-power density batteries. The total near-term effort of a Nimbus demonstration package could cost approximately $200 thousand.

When power requirements are reduced, efforts in the area of microminiaturization (at a minimum starting cost of around $300 thousand) could be undertaken. This will, in part, depend on parallel technology developments in oceanographic systems and other areas.

For the development of environmental sensors and platforms, again there is a high degree of commonality. However, the water and marine environments create the need for specialized effort. Platform development from other NASA projects will contribute a great savings in time and effort as reflected in the budget allowance. The same spin-off applies to the data-collection methods developed for satellites and aircraft. Previous tasks dealing with wildlife monitoring likewise affect the budget allowance shown in figure 26 for the data-collection area. The funds for data interpretation, models, and data distribution are largely for operations during the demonstrations and interface with the user agencies.

Further cost breakouts on an individual task basis are summarized in figure 27. This figure also includes those tasks in addition to hardware development. The total cost is just over $7 5 million, to be spread over about 13 years. Much of the work will be subcontracted to private industry.

The approach in animal instrumentation development would be managed by biologists and engineers already engaged in biosensor research and development at Ames. Outside contracts through RFP's would be used to enhance these efforts. The use of approved animal-handling facilities and accepted legal animal procurement and investigation methods should ensure success in the development of hardware that will function reliably in the field. NASA's proven approach of systematic development using modular component design, rigorous testing in laboratory and field, quality control, and demonstration will be followed throughout the program.

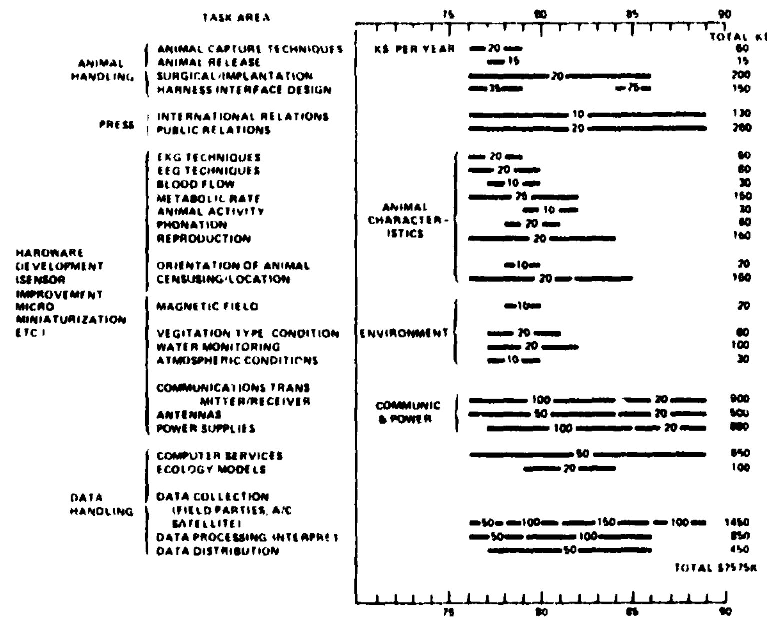


Figure 27.– Wildlife Monitoring Program tasks.

PROGRAM MANAGEMENT

Within NASA, the Wildlife Monitoring Program will utilize the expertise and facilities of four NASA centers. At NASA Headquarters, progra 'irection will be provided by a collaborative effort between OA and Code MM. OA will have responsibility in areas of communications and satellite systems; MM will have responsibility in biological areas. NASA Headquarters will organize and receive input from an advisory group of outside scientists. This group will review each task and project for scientific and technical content on a biological and physical basis as well as determine if the users needs will be met. Headquarters will also have key input from the Council of Environmental Quality. This Council, which is aware of the users' needs, will evaluate the applicability of the tasks and help to coordinate the efforts with the user agencies.

As lead center, ARC will collaborate with the other centers and users to achieve the objectives of the program. The remote sensing aircraft of JSC and ARC will be coordinated to augment ERTS information and enhance the field party work. With its unique facilities and experienced personnel, Wallops will conduct the bird-tracking program. GSFC will develop radiotelemetry systems that include the development of sophisticated antennas, power packs, and transmitter/receiver systems. The responsibility for making these systems compatible with satellite systems and providing common approved system specifications to investigator ... users will rest with GSFC.

Specifically at ARC, the animal interface will be handled both on the harness/collar level and the bioinstrumentation development and use level. ARC will handle the coordination of data collection and distribution tasks for location, behavior, and environmental data. Combined components of harness and telemetry as well as the individual bioinstrumentation will be tested at ARC under R. and Q.A. inspection. Figure 28 is a diagram of the organizational interfaces.

From the beginning of activity, including the formulation of the Program Plan, user agencies will usually be involved on a cooperative basis; they will not generally be funded as investigators. During and after demonstration tasks, users are expected to become more and more involved - taking over investigations by fielding ground truth parties, reading out data, and applying management models. The investigation teams will operate from rigorous standing instructions patterned after NASA's systematic methods for management and technical development. These systematic methods will include established planning, testing, and approval cycles. Investigation procedures will be approved before significant effort is expended. Systematic control of hardware configuration and animal handling techniques will be exercised. An accurate record of the procedures. instrumentation, and data collected will be kept. From design analysis and experiment readiness reviews, it will be determined what quality assurance inspection procedures are necessary. Both biological and technical disciplines will be subject to careful control to ensure production of useful results.

The total Wildlife Monitoring Program funding is givne in figure 29. Responsibility assignments (fig. 30) show the tapering of NASA activity. Heavy involvement occurs in the early years during the development and demonstration of NASA technology, and then it drops gradually from 1976 through 1984. From that point, there is rapid disengagement of NASA as an active participant, with

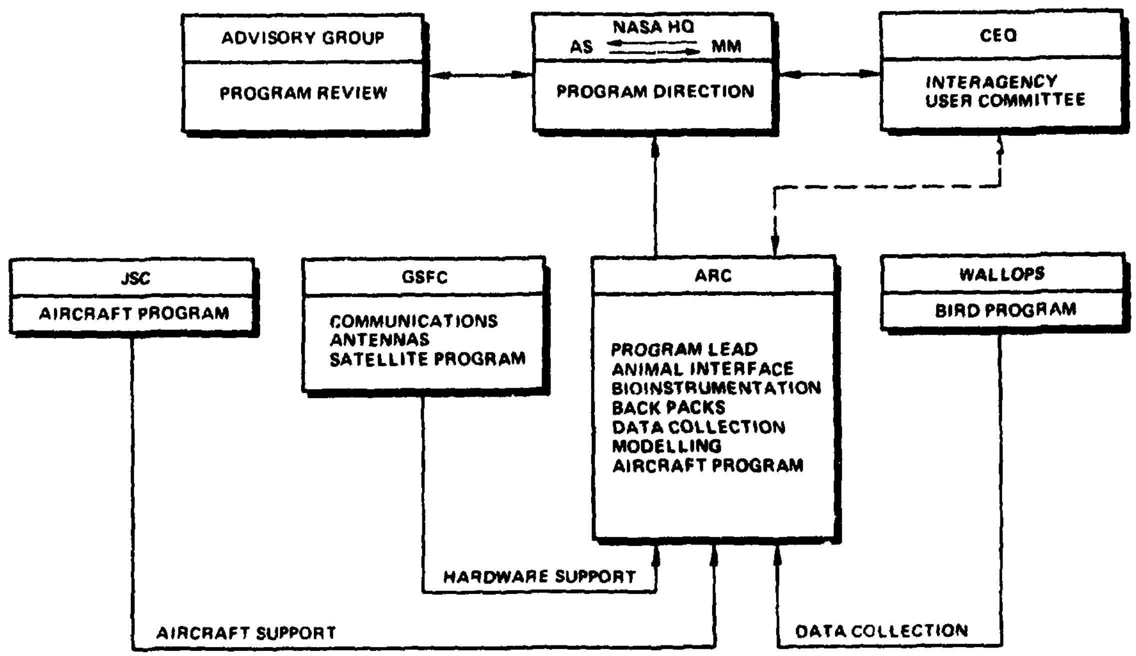


Figure 28.– Wildlife Monitoring Program management.

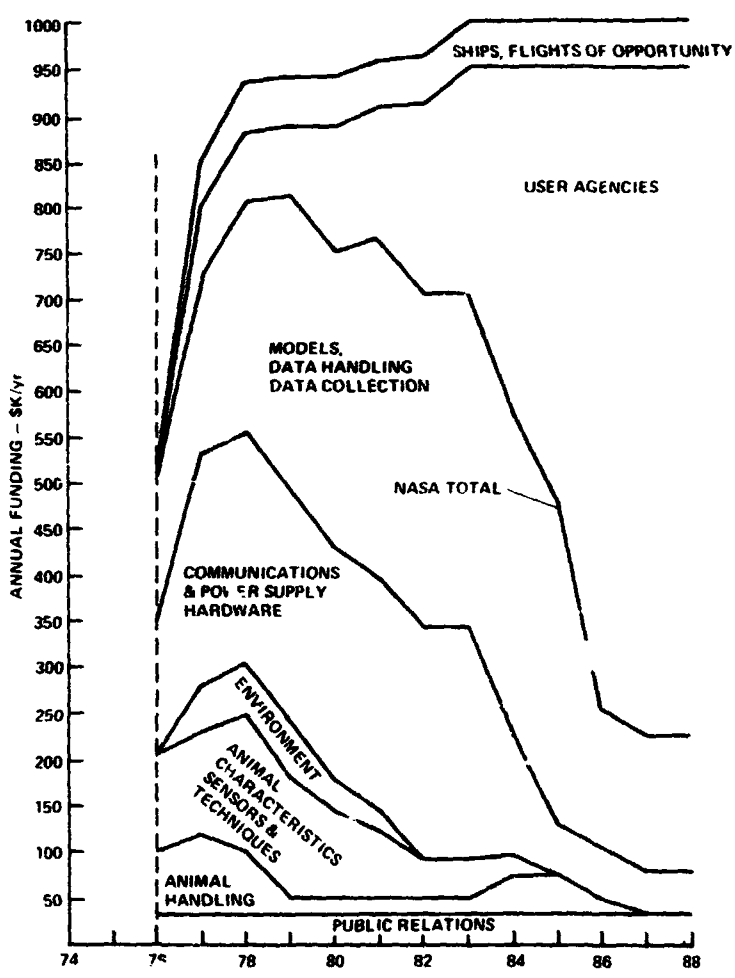


Figure 29.– Wildlife Monitoring Program funding.

user agencies assuming all lead roles. These changes are likewise reflected in the total program funding as indicated in the five major development areas of figure 29.

Good public relations is considered an essential component of the management plan. The wildlife area is particularly sensitive because of potential criticism from conservation and animal welfare groups. To a considerable degree, such criticism can be avoided if the groups can be shown that the goal of the program is in large part, conservation, and that the welfare of the animals is a high priority item. The groups can be informed in various ways, sometimes best through the investigators, many of whom already have links with them. The NASA Public Relations organization will, of course, have an essential role and will keep in close touch with activities both at Headquarters and at the centers. OA, MM, and the Office of the Administrator will be kept informed by the centers as each experiment gets underway.

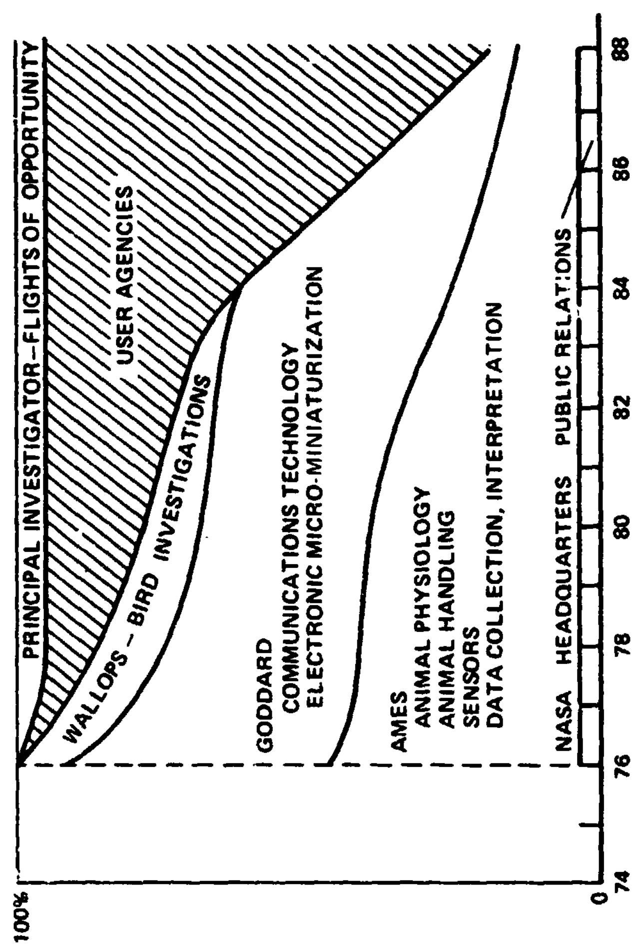


Figure 30.– Wildlife Monitoring Program responsibility.

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APPENDIX A

1973

Santa Cruz Summer Study

of

Wildlife Monitoring

INTRODUCTION

Purpose of the Report

The purpose of this report is to show the importance of our wildlife resources and to show that their management, conseration and rational use are national goals based on laws, treaties and agreements binding between the United States and other countries as well as upon agencies at the state and federal levels. In order to fulfill the intent of their commitments federal and state agencies (herein referred to as USERs) have established programs for which information is needed on habitat, censusing, movement, location, physiology and behavior of animals and their populations.

The report reviews the application of technology to these programs, showing how instrumentation systems and techniques can be matched with specific requirements for bilogical data. Engineering to improve presently used wildlife management methodologies and ways of rectifying their limitations are also discussed. Applications, uses and costs and benefits are presented in detail as well.

Two systems, RAMS and Omega/OPLE, were selected by consensus as having the greatest capability and best specifications for locating animals and receiving needed biological and environmental data from the largest variety of animal types inhabiting terrestrial, aquatic and aerial habitats.

Animals to be used in the program were arrived at by consensus on the basis of criteria described in Chapter III.

Development and fabrication of animal package instrumentation were discussed. The needs of USERs were analyzed in terms of the required degree of miniaturization, type of packaging and harness necessary for use, with little or no modification, on the smallest (feasible) as well as the largest animal to be studied.

The importance of good public relations is recognized, and suggestions for assuring favorable public response are presented in Chapter V.

Significance of the Program

For the purpose of this report, "wildlife resources" refer to animals found or managed in a largely wild state. Thus they include traditional wildlife -- wild terrestrial and aquatic vertebrates (mammals, birds, reptiles and fish), along with their habitat -- wild flora, wild invertebrates and domestic livestock under open range conditions and including those range conditions.

The resources are closely interrelated. Each is an integral component of a natural or man-modified ecosystem. Ultimately all are components of the bioshere, and significant alteration of any one component will have some impact on the equilibrium of the entire system. Each resource plays a role in maintenance of the health and stability of our global life support system, although with our present state of knowledge, it is rarely possible to define that role with any precision.

Wildlife resources are a complex and living form of national and international wealth that can be renewed or destroyed. They can be managed to meet the numerous needs of our society — including their role in maintenance of environmental health and quality.

Information gathered by the proposed techniques will be applicable to improving commercial harvests of wildlife resources which are major factors in the world's food supply. It will also be important for the management of non-commercial wildlife resources which contribute to a very large and significantly increasing range of recreational, aesthetic and educational uses. These include, among others, the relatively stable demands of hunting and fishing and the rapidly expanding nonconsumptive uses of wildlife, including tourism. Many species serve as sensitive indicators of environmental degradation such as increasing pollution. These species also need to be identified and their presence detected.

Limited success in dealing with wildlife has been achieved through the work of wildlife biologists using visual observation methods and simple measurement techniques to understand the details and requirements of animal life. Much additional effort is needed in this area today. Yet this kind of work is enormously time-consuming and has required the efforts of generations of specialists.

The synoptic views, the resolution and the near continuous data gathering capability of satellite systems, as well as the data reduction methods offered by space technology, may well provide our only possible route to understanding and managing wildlife resources and their habitats a and enhancing the possibility of meeting the continuous and growing need for recreational and commercial benefits of the resources.

Ground radio tracking and biotelemetry of the physicology of animals have already made some contributions to an understanding of animal migratory behavior. Yet many problems remain unresolved because of the limitations of ground and even aircraft tracking technology. Satellites permit tracking and monitoring of wild animals on a worldwide scale during the day and night and in all seasons. Global coverage is attainable in a single day or less, and neither bad weather nor inaccessibility deter operations.

Tracking can be accomplished where animals are in rugged terrain, birds are making lengthy migrations at high altitudes or marine animals are covering great distances at sea. Satellites are suitable for automatic and regular recording of data over a long period of time, especially for wide-ranging animals, and can gather data almost simultaneously from a large number of instrumented animals of the same spcies, either widely separated or in a herd. On a realtime basis satellites can monitor numerous animals and their environments over extensive areas such as a desert, grasslands or the length of a large river system. While tracking is being done, optical surveillance of an animal's environment can also be made, with both electronic tracking and optical surveillance contributing to fuller and more fruitful results.

CHAPTER I

NATIONAL NEEDS AND APPLICATION

Legislation

National recognition of the importance of wildlife resources and the increase of public pressure for their conservation have resulted in a record volume of legislation over the past few years. A list of particularly pertinent laws, treaties and international agreements is given in Appendix C. Extracts from a few are listed below (underlining added), mentioning the specific data required to fulfill the laws:

- Convention for the Establishment of an Inter-American Tropical Tuna Commission (p. 81)

  Article II. "The commission shall...

  1. Make investigations concerning the abundance, biology, biometry, and ecology of...tuna in the waters of the eastern Pacific Ocean..."

- International Convention for the Northwest Atlantic Fisheries (p. 81)

  Article VI. 1. "The Commission shall...

  a. make such investigation as it finds necessary into the abundance, life history and ecology of any species of aquatic fish..."

- International Convention for the Conservation of Atlantic Tunas (p. 81)

  Article IV. 1. "In order to carry out the objectives of this Convention the Commission shall be responsible for the

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study of the populations of tuna and tuna-like fish... Such study shall include research on the abundance, biometry and ecology of fish; the oceanography of their environments;..."

- Marine Mammal Protection Act, P.L. 92-522, October 1972 (p. 85)

  Sec. 1362 (2). "The terms 'conservation' and 'management' mean the collection and application of biological information for the purpose of increasing and maintaining the number of animals within species and populations of marine mammals... Such terms include the entire scope of activities that constitute a modern scientific resource program, including, but not limited to, research, census, law enforcement, and habitat acquisition and improvement..."

  Sec. 1373 (d) (1) "...the Secretary (of Commerce) shall make available to the public...

  (1) a statement of the estimated existing levels of the species and population stocks of the marine mammal concerned:..."

- Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere (p. 81)

  Article IV. "The Council shall ...undertake ...cooperative research and development projects... (for) proper utilization of living aquatic resources

- P. L. 86-686, (Research and Education Relating to Fish and Wildlife)

  Sec. 5: That such experiments and investigations as may be necessary in determining the life histories and habits of forest animals, birds and wildlife..."

USERs' Stated Needs

As shown above, the missions of most federal and state agencies are specified in legislation requiring programs for the management, protection and proper use of wildlife resources and habitats within their jurisdiction. The USER agencies, in meetings with NASA in December 1972, February 1973 and representatives of the scientific and technological communities in April 1973, described their major data requirements for fulfilling these missions. They are:

- Animal censusing and population synamics; a continuing check on the health and vigor of animals and their populations;

- Location of animals to determine migratory paths, speed and direction of movement; changes in movement patterns during stages of their life history;
- Habitat characterization; description, mapping and determination of the boundaries of animals' ranges;

- Physiology; baselines for detecting changes relating to health and vigor; physical analogs of biologic systems;

- Behavior within the habitat; feeding and breeding; reaction to environmental changes.

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In the past such data requirements could not be acquired for most animals except in a limited way by visual observation on the ground, banding or other means of tagging, photography or visually from low-flying aircraft, clues from known behavioral patterns and other less than satisfactory methods.

The breadth and scope of the required data plus the widespread spatial distribution of data sources have necessitated new methods and applications of appropriate technology. In this report the problems of censusing, detecting and locating animals and monitoring their physiology and behavior are given greater emphasis than habitat characterization, since the latter can be accomplished to a useful extent by ERTS-like systems and facilities already available or in the planning stage.

A complete list of the USERs of aerospace technology and their statements of data needs are given in Appendices A, D and E. Major interests are also shown in Table 1 (p. 66). A few examples are presented here:

- Organizations within the Departments of Commerce, Agriculture and the Interior and within fish and game departments of many states are committed to improvement of domestic stock and free-living animals on rangelands. Telemetry permits the location of large terrestrial mammals and the tracing of their seasonal migrations and other movements. From this information responsible officials can predict where roads, dams and construction sites are likely to contribute to hazardous situations and where vegetation is liable to be trampled, etc. In Alaska the location by satellite of caribou herds can save Eskimo villagers much time and dangerous activity in finding winter sources of meat. In addition to the animals themselves, their habitats must be measured and characterized with respect to quality and composition. These factors can often be determined by monitoring for the presence or absence of indicator species.

These USER agencies are also concerned with problems related to the spread of diseases which are transmitted by or attack livestock or poultry. Potential disease reservoirs must be located and their migratory patterns traced. If individual animals or herds can be pinpointed for time and location, their speed and direction can be determined and predictions made about the spread of the disease.

Table 1. WILDLIFE RESOURCES MONITORING: USERS AND MAJOR REQUIREMENTS

USERS	MGMT.	CONSERV.	USE	REG.	HAZARDS	POLL. & ENVIRON. QUALITY	BEHAVIOR PHYSIOL. ECOLOGY	LOCATION MIGRATION SURVEILL.	LAND USE	HABITAT MONITOR-ING	DISEASE SPREAD/PLANT & ANIMAL
AEC								X	X		
USDA	X						X	X	X	X	X
FOREST SERVICE	X							X	X	X	X
COUNCIL ON ENVIRONMENTAL QUALITY	X	X				X	X	X			
COMMUNICABLE DISEASE CENTER	X						X	X			X
FAA					X		X	X			
HEW	X					X	X	X			X
INTERIOR DEPARTMENT	X	X					X	X	X	X	
BUREAU OF SPORT FISHERIES AND WILDLIFE	X	X					X	X	X	X	X
NOAA	X	X	X				X	X		X	
PUBLIC HEALTH SERVICE						X	X	X			X
STATE DEPARTMENT								X		X	
STATES	X	X	X	X	X	X	X	X	X	X	X
USAF					X		X	X			
CORPS OF ENGINEERS							X	X	X	X	
COAST GUARD				X	X		X	X		X	
USN					X		X	X		X	

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The National Oceanographic and Atmospheric Agency in the Department of Commerce requires methods for measuring and monitoring marine resources: fishing productivity, fish population density and vigor, migration routes of commercial and sport fish, related fish behavior and physiology, effectiveness of catch methods, identification and location of polluted water masses by indicator and sentinel (deliberately placed) organisms, and condition of large marine animals, many of which are endangered. Location of fish schools on a real-time basis will direct fishermen to the most productive waters; location of fish schools inshore during egg-laying season will identify small fry habitats, allowing officials to take necessary precautions against industrial and human pollution and other disturbances.

The Bureau of Sport Fisheries and Wildlife of the Department of the Interior has statutory requirements for studies (some with NOAA) of predators and other animals and their habits, migration, behavior and populations (polar bear, sea otter, walrus, manatee, caribou and birds); and for assessment of the effects of pesticides on birds and fish and of the movements of wildlife and waterfowl migrating between the U.S. and other countries (especially Canada and the U.S.S.R.). The latter responsibility it shares with the State Department.

The Communicable Disease Center of the Public Health Service in the Department of Health, Education and Welfare needs information about migrant animals spreading various diseases: equire encephalomyelitis, Newcastle disease, Dutch Duck plague (which killed 30,000 ducks in 15 areas of South Dakota in Jan./Feb. 1973), hog cholera, cattle fever, ticks, hoof and mouth disease, rinderpest, African swine fever and other diseases of swine.

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Diseases carried by insects and other animals which infect humans also must be monitored so they can be controlled.

The Atomic Energy Commission's concern is with the location of power plants in areas where an adverse effect on local animal life is probable. The Commission needs to know whether there are schools of fish that might be killed or driven off by an increase in water temperature from the plant's cooling system.

The Department of Defense has many and widely varying contacts with the environment in the realm of personnel health and safety and management of the vast land and water areas under its control. Bird hazards to aircraft pose a constant threat to life and cost millions of dollars in lost equipment each year. Locating bird flocks on a time, speed and direction of flight basis can warn of potential danger in aircraft lanes to commercial, private and military aircraft. The Federal Aviation Agency and the Interagency Committee on Bird Hazards to Aircraft are also vitally interested in this application of space technology.

The U. S. Army Corps of Engineers must avoid deleterious impact on wildlife from land dumping, reservoir construction, water impoundment, channel modification and changes in wetlands and land configurations along migration routes and on breeding grounds.

The U. S. Navy is constrained to maintain shore installations, especially in remote areas and on islands where man's impact could be especially damaging to local animals. Information on the distribution and migration routes of marine mammals, sharks and noise producing fish is important, especially when and where large concentrations of these species occur, since they may interfere with the operation of underwater equipment.

Applications

The data gathered from position/location and monitoring systems will have even wider application than the specified needs of USERs. In a more general way they will have application to commerce in:

- Improvement of commercial productivity in the management of food resources (including animal protein, fisheries, agriculture and forest crops) and non-food animal products (including leather, furs, bone, bone meal, oils and lubricants).

- Improvement in the management of domestic species on rangelands.

- An increased base of knowledge for regulations and activities regarding the recreation industry (including hunting, fishing, photography and zoos).

- More effective violator control.

- Detecting effects of too much grazing, hunting or fishing and assisting regulating agencies to determine effective "bag" limits, additions to endangered species lists or changes in methods of regulating commercial fish catch.

- Detecting changes in ecology or food sources due to contaminants, pesticides or other types of pollution.

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- Determining the carrying capacity of land being used for both domestic stock and agriculture.

- Forecasting overgrazing, the formation of deserts, etc.

Applications are also found for problems of <u>disease, public health and welfare</u> such as:

- Pollution control, by employing indicator species or sentinels (species deliberately introduced because of their sensitivity to specific kinds of pollution).

- Plant and animal diseases carried by migrating animals.

- The concentration of pollutants in body tissues because of contaminated food.

- Wildlife as a source of medicinals.

Further application in <u>biology and medicine</u> are:

- Use of wildlife biological systems as analogs for human physiology and behavior (adaptions of deep diving mammals, navigational ability of migrating animals, etc.).

- Improvement of environmental quality.

Applications in <u>land use</u> concern:

- Competition among domestic stock and wildlife as well as between agricultural and natural lands.

- Allocation of grazing and forested lands for domestic and wild stock as well as for grain crops and for habitats and food for waterfowl.

- Proper use of land, including waterways and ponds to alleviate the problems of migratory birds feeding on grain crops.

- Proper use and allocation of grazing areas to minimize the danger of overgrazing and even, ultimately, creating deserts.

Further applications of data on wildlife behavior and ecology are in such problem areas as:

- Land use in construction practices (housing developments, reservoirs, dams, roads, communication facilities).

- Agriculture and urbanization.

- Conservation and agriculture.

- Conservation and tourism.

- Agriculture, grasslands and forest management.

Applications in tourism, travel and recreation occur in the:

- Impact on the environment from camping, fishing and hunting.

- Effect of tourism and conservation practices on wildlife ranges and habitats.

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- Management of game preserves and zoos.
- Impact of recreation on the well-being of the human population.

Applications in ecosystem response are:

- Improved understanding of the interdependence of food chain organisms.
- Effects of the accumulation of contaminants in the environment and in animals and plants.
- Energy transfer within and between ecosystems.
- Effects of accidental or premeditated ecosystem and modification such as stripmining, stream damming, deforestation, etc.

Applications for legislation are:

- Design of effective policies and regulations for dealing with wildlife and wildlife habitats.
- Surveying and regulating fishing activities in waters of interest to the United States.
- Formulation of international agreements which recognize the ecological implications of regulating fishing in international waters and which deal with migration of disease-carrying animals across national boundaries, as well as with conservation of species crossing boundaries or living in the open ocean.

CHAPTER II

COSTS AND BENEFITS

Benefits from the program derive from improvements in efficiency and economy of data acquisition and in greater understanding, conservation and inventory. Remote sensing capabilities are already accomplishing tasks that are not possible with direct or surface-based techniques or that can do a far better job, frequently with significant gains in efficiency and economy. For example, making a single transect of the world's oceans by ship requires many months of planning and execution at a cost comparable to that of a satellite making continuous daily transects, each far more comprehensive than is possible by ship. Application of the technology will be essentially continuous. A relatively short term investment in application or development of relevant technology will produce critically needed long term returns.

Benefits are evident especially when the economies affected are compared with existing research and monitoring efforts. Gains including greater harvests, decreased loss or more effective preservation are derived from better understanding and conservation management of resources. Areas of major benefits have been identified, providing some perspective on the magnitudes of both the costs and benefits involved.

Aquatic Species

The annual world fisheries harvest amounts to about 60 million metric tons (Ref. National Fisherman, Sept. 1973). Included in this is the $450 million per year U. S. Yellowfin tuna industry. (In 1967 commercial fish landings worldwide were worth $2 billion, the U. S. Fin fish catch being worth $170 million. (Ref. R. W. Bell, "Relation of the Production Function to the Yield in Capital for the Fi hing Industry — Recent Development and Research in Fisheries Economics, 196 "). In addition to commercial fisheries, the salt water sport fishery in the U. S. also has high economic value (523 million recreation days were spent in salt water sport fishing in 1967). Supplies and services purchased for the sport in 1965 equalled $575 million, and the sport catch amounted to 740,000 tons (CEQ estimate).

Many fisheries have now declined drastically due to overfishing and/or other factors. One of the more extreme cases in the whale fishery, which at one time provided about 3.5 billion pounds of products a year worldwide. Shellfish are likewise valuable (the U. S. oyster industry is worth some $50 million per year), and perishable -- oysters are especially vulnerable to pollution. The recent ban on clamming in the Chesapeake Bay because of pollution cost an estimated $5-10 million a year (Ref. National Fisherman, Sept. 1973).

Schooling fish fisheries such as the anchoveta off Peru (about 12 million tric tons a year at its peak) have proven capricious and difficult to predict or control. The Peruvian anchoveta fishery in 1970 accounted for 22 percent (about 460 million tons) of the world catch. In 1972 it produced only 112 million tons (Ref. C. P. Idyll, Scientific American, June 1973). Anchovetas are a major factor in the cattle feed industry, and their decline has contributed to price increases and shortages that have swept the world cattle industry and have struck hard at the U. S. Economy. The cyclic rises and falls in the anchoveta industry need to be understood worth $170 million. (Ref. R. W. Bell, "Relation of the Production Function to the Yield in Capital for the Fishing Industry -- Recent Development and Research in Fisheries Economics, 1967"). In addition to commercial fisheries, the salt water sport fishery in the U. S. also has high economic value (52_ million recreation days were spent in salt water sport fishing in 1967). Suppl... and services purchased for the sport in 1965 equalled $575 million, and the sport catch amounted to 740,000 tons (CEQ estimate).

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in order to permit predictions and good management.

If useful knowledge of such fisheries could be obtained from the wildlife monitoring techniques suggested here, economic stability around the world would be enhanced.

Not only would the fish catch in open water be more predictable, but the increased knowledge of life cycles and larval distribution could provide a basis for a profitable fish farming enterprise.

The yellowfin tuna seine industry ($2 billion per year in terms of national cash flow) is highly dependent upon porpoise schools. By using them as beacons of tuna schools swimming beneath, fishermen are able to increase their efficiency fivefold, crucial in this highly competitive business. Yet the porpoises are destroyed at the rate of about 300,000 per year by becoming entangled in fish nets. There is also a fear that porpoises may become subjects of direct exploitation. For these economic and conservation reasons the porpoise population must be monitored.

The decimation of whales, especially in the Antartic, has undoubtedly contributed to large population increases in species such as the crab eater seal, which also feeds on krill. These animals now face major exploitation, but little is known of their population structure or numbers.

Portions of the oceans that are more or less compartmentalized -- water bodies such as small seas, gulfs and other small water masses -- need coherent management of their ecosystems. Contiguous nations are coming to understand that they must cooperate to preserve these regions. Data gathering and processing needs are very great, as are the international values involved.

For example, the Bering Sea, which lies over the largest continental shelf in the world and hence is very productive, is now a burgioning fishery exploited by the U. S., Russia, Korea and Japan. It is very vulnerable to pollution and overexploitation, and the need for effective ecosystem monitoring is critical. Countries using the Bering Sea fisheries now operate under commercial fishery pacts and treaties based on wholly inadequate, non-systematic data. The inadequacy of the information for practical management of the Bristol Bay salmon fisheries is seen in the decline from a $50 million dollar per year industry to $2 million per year. And the 1973 salmon fishery yield is the lowest on record since the turn of the century when management began. Both the California sardine and the Hokaido herring industries, which once produced a very high yield, are now almost decimated because of lack of knowledge about the schools, which resulted in severe overfishing.

Benefits from inventorying and monitoring fish fry in coastal zone habitats in 1969 were estimated at $15 to 20 million; improved and more intensive management will raise the value to an estimated $25 to 34 million in 1973 (Ref. "Cost/Benefits Study of Earth Resources Observation Satellite System - Costal Management", prepared for RCA-AED, Princeton, N. J. , June 30, 1969, by K. Heiss and E. J. Greenblat).

Present methods of population analysis for marine animals are very expensive in time, money, equipment and manpower and are inadequate (see pages 41-42). Yet because of the crucial nature of the resources involved, widespread work is still carried out with old methods.

In a 1969 tuna study it was estimated that if there were a 59 percent reduction in search time and a 25 percent increase in catch per trip, there could be about a $2 million reduction in annual operating costs and $6.4 million reduction in fleet investment (Ref. V. J. Norton, "Some Potential Benefits to Commercial Fishing through Increased Search Efficiency: A Case Study", prepared for the U. S. Geological Survey, January 1969).

Shiptime is enormously expensive $2 - 4,000 per day or .75 to 1.5 million per year per set of data points) for even a modest research vessel, exclusive of scientific staff and other expenses. Dozens of such ships may be required where a single satellite operation would suffice. Remote sensing through aerial and satellite surveillance would not only give much better coverage but could also produce real-time, essentially synoptic data over great geographic areas. Because ocean dynamic processes and distributions can change rather rapidly, these methods open new research possibilities.

Accurate and fast sensing, relay and data processing systems are needed to provide the real-time data needed for management of catch and escapment rates. More and improved data to back up management and bargaining decisions at state and internation levels can be gathered from remote, hostile seas by communication relay and other satellites that can give synoptic views of remote areas.

Commercial Harvest of Terrestrial Wildlife Resources

Domestic range animals, predominantly cattle and sheep, are largely unsupervised and have many characteristics in common with wild species. They share rangelands and, in some cases, compete for food with wild species. Degradation of rangelands through overgrazing or other factors usually affects both wild and domestic species as well as the land itself. In 1968 grazing land in the United States amounted to 68 million animal unit months (AUM),,and the land value in forage was about $1.7 billion. Annually the value of forage is about $180 million (Ref. "Economic Estimates - 1968"). Application of remote sensing capabilities to wild rangeland management can produce direct benefits through continuous inventory and monitoring of resources to assess habitat suitability as related to animal populations and other use pressures. This results in management information which can be used for direct economic exploitation of a multiple use wild land resource which includes domestic livestock. Information useful to assess biological and environmental suitability for range wildlife and livestock is precisely the same information that resource managers use for wise "harvesting" of resources. For example, cost/benefit studies currently being performed in the Earth Resources Survey Program in the categories of forest and range inventory will be directly applicable for assessment of habitat suitability.

The proposed physiological instrumentation of indigenous and sentinel species should provide indirect information on site quality. The number of hours that animals engage in feeding is related to the abundance and quality of the food supply. While this may be a particular group of plant species, it is quite feasible and reasonable to use botanical ecological relationships to derive inferential data on the total habitat. However, the number of animals in any population that must be instrumented to provide the necessary statistical confidence in data as applied to the entire territory of the species must be determined.

The total capital value of U. S. domestic range animals is about $1 billion (CEQ). Benefits related to range livestock could be more efficient and/or less destructive use of rangelands, better use of supplemental feed, fewer winter deaths and less summer dehydration, high reproduction rates and decreased research and monitoring costs to federal and state governments.

Recreational Values

Recreational benefits from proper wildlife management include photography, nature study, camping and hiking, sport fishing and hunting and associated travel and tourism. Benefits can be determined in terms of direct capital expenditures of equipment and travel, of the value of pertinent industries and in the social benefits to the public. An example of the recreational contribution is the addition of an estimated $1,000 + to the economy of Wyoming for each elk taken by hunters, who shoot about 3,000 a year.

It is also necessary to keep abreast of increases in demands for consumable recreational species. For instance, the 25 percent of the U. S. opoulation who fish for sport today spend about $3 billion per year (Ref. Weiss and Goldblat, 1969). The number of anglers is expected to increase.

Meeting their increased demand will require more information about fish.

Many wildlife species found in national parks, national forests and wildlands satisfy the aesthetic desires of an increasing number of persons and benefit businesses catering to camping, touring, photographic equipment etc.

The extent of interest in wildlife is shown by efforts made in developing wildland recreational facilities. For instance, one-third of our nation's land is federally owned and includes 181 million acres in national forests, 6 million acres in national grassland, 84,000 miles of fishing rivers 15,000 natural lakes (1.5 million acres), 3,200 reservoir empoundments (1 million acres) and 15,000,000 acres of wilderness area, all of which are used for wildlife-based recreational activities (Ref. Third Annual Report on Environmental Quality, CEQ).

Public Health, Safety and International Trade and Associated Use of Indicator and Sentinel Species

Animals have historically been used as sentinels of environmental dangers, the classic case being the canary in the coal mine. Currently many animals are used in pesticide monitoring because their sensitivity is so great, they respond to very small amounts of dangerous material. Animal diseases can affect humans indirectly through the food chain or directly. Tubercular spondylitis, for example, would not have been controlled in children without the successful eradication of tuberculosis in cattle. The . . . plete eradication of a disease, i.e., the finding of the last infected animal, is very high. Fortunately, in the typical public health program it is possible to establish a monitoring program utilizing indicators and sentinels which keep the health services informed about the presence and spread of a disease. Even though the disease organism has not been completely eradicated, the disease can usually be kept under control.

Instrumenting animals to detect rises in temperature, decrease in feeding when food is available and other physiological responses to infectious disease could signal the emergence of a disease before it spreads. Monetary savings could be enormous.

The alternative of disease control and eradication is exemplified by cost/benefit studies performed on hoof and mouth disease. Any country with the disease can expect to lose 25 percent of the value of meat, milk and other livestock products. (An outbreak in the U.S. would cost $250 million.)

In other disease situations, e.g., multiple host diseases, disease emergence data would permit the start of immunization programs in time to protect alternate host species, animal or man.

Of direct interest to public health and safety is the problem of aircraft collision with birds. The U.S. Air Force alone has estimated this proglem costs them several million dollars annually, let alone loss of life. Where migratory routes are involved, airlines could adopt routes to avoid birds. Mapping and monitoring migratory routes is feasible with modern cameras and film. Census information is now obtained with these systems for some species, but even in the case of the whooping crane, the migratory route is only crudely known. This problem could be solved immediately by a combination of telemetry and modern remote sensing systems.

Remote sensing can have important implications for international cooperation on disease control. Animal diseases do not recognize national boundaries. Communication between countries on disease incidence exists. Reports are prepared by the Organization of Internation Epizooties (O.I.E.) monthly and distributed to all member countries. Explosive disease outbreaks are reported at once by the fastest available communication means. Instrumentation of selected domestic and wild species can help this vital international system.

Endangered Species

Most, though not all, officially designated endangered species are insignificant both in terms of biomass and numbers. Considering this their value lies in four areas:

(1) potential productivity and commercial value should species recover;

(2) maintenance of unique genetic strains;

(3) potential contributions to the ecosystem;

(4) social values.

A few species fit in the first category, such as great whales, bison and muskox. But the tiny honey-creepers (birds) of Hawaii, even if restituted, must be judged on some other basis. It is difficult to assess the value of genetic conservation except as a contribution to improved domesticated forms. The bison, for example, is now being used for crosses with beef cattle and as such may be of considerable importance.

It is likewise difficult to assess the potential contributions of endangered species to an ecosystem's health and stability. However, because of social values we have a need to preserve endangered species. To the legislator the public pressure resulting from social concern is paramount.

Many people feel the world would be of lesser value if man were to cause the extinction of the California condor, the jaguar or great whales. Their indignation has caused the passage of the Endangered Species Act, among other legislation, and has resulted in a wide ranging program for preservation.

Millions of dollars have been spent for intangible benefits derived from preservation of endangered species. The Forest Service has in some cases set up protected areas around bald eagle nest sites and forbidden logging there. Highways have been rerouted to avoid habitats of endangered species.

Improved management through monitoring would prevent species from becoming endangered, and such costs would not have to be incurred.

Scientific Benefits and International Transfers

The majority of the practical benefits described in the preceding sections will result from the formidable increase in knowledge and understanding of wildlife and its ecology.

The ability to monitor species in reasonable numbers and to record their environment simultaneously will permit more precise determination of the way environmental factors modify their health, populations, behavior and physiology. Conversely, the influence of animals on the environment wi will be better understood.

It will be possible to construct models of the particular ecosystems involved, and these models in turn will permit predictions of the way natural environmental changes or human intervention will change the populations, distribution and behavior of a species. Predictions will then be further tested to verify and improve the models.

The combination of wildlife monitoring by radio tracking and remote sensing will permit, for the first time, good statistical determinations of wildlife populations and behavior patterns, without which it is often impossible to apply observations of a few animals to the biology of a whole species.

Increased scientific knowledge of wildlife species could be obtained, in a limited number of cases, with conventional field observation techniques from the ground or oceanographic vessels. However, the cost of such observations would be far greater when compared to that of aerospace technology.

While most of the speci ic projects proposed for individual species in this program refer to wildlife of national interest, the techniques will usually have application to species anywhere and will therefore be of considerable value to other nations and to improved understanding for hydrology, geology, oceanography, agriculture and forestry, so will the program developed here foster an international structure for wildlife science and corresponding benefits for all nations involved.

Compliance with Legal Requirements for Environmental Quality and Resource Availability

The United States is committed to maintain or improve environmental quality and to husband its natural resources. Many laws and regulations h have been promulgated at all levels of government, stemming largely from recognition that benefits -- improved quality of life -- will inevitably accrue.

Quality of life is measurable in simplistic terms such as the quantity and price of meat on the table or the ability of the air to sustain life, or in extremely complex (and as yet only partially understood) terms that concern the maintenance of ecosystems for a maximum sustainable yield or the long-range ability of this planet to sustain human life. That these laws are needed and have already resulted in measurable benefits have been demonstrated economically and in other less easily measured ways.

We will need new laws and regulations and revisions of the old. They must be based on ever increasing information derived from the complex living systems they are to regulate or control, but there is decreasing time available in which to get the information. High quality technology is mandatory for producing high quality information which will lead to great benefits to mankind.

Many present laws already require the information this program would provide. Examples include fish and wildlife laws, Endangered Species Conservation Act, Marine Mammal Protection Act and National Environmental Policy Act.

Compliance with all these laws entails very considerable annual expenditures by state and federal agencies. The estimated annual expenditure on wildlife management (not including domestic livestock) is now $140 million, and federal funding for environmental enhancement activities involving wildlife resources (excluding domestic livestock) in fiscal year 1973 is about $340 million (CEQ estimate).

Magnitudes

Previous subsections point out that although some dollar figures are available, many benefits to be realized from improved wildlife conservation and management are not quantifiable. However, even the few figures cited indicate that the annual cash worth of wildlife resources can be measured in billions of dollars and that annual federal and state expenditures reach hundreds of millions of dollars.

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CHAPTER III

ANIMAL PRIORITIES AND HANDLING PROCEDURES

Animal Priorities

In order to make a wise selection of the species to be monitored and one that is neither arbitrary nor capricious, statutory requirements USER needs and the broad ecological value of the information requested were considered based on the following criteria:

- o animals of special interest to the greatest number of federal, state and non-governmental groups;
- o those with relations to man which require urgent study, i.e., disease vectors and other hazardous forms;
- o those which are:

  endangered

  commercially valuable

  considered to have social or ecological impact;
- o likelihood of development of a practical monitoring system in the near future;
- o feasibility of locating the animal of choice in the field.

Where one monitoring technique or piece of equipment had a broader application than others and where the animal of choice was representative of a category of animals haveing similar characteristics, the rating was higher.

The resulting priority list of animals is:

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1. Waterfowl (geese, ducks, swans, etc.)

   Predatory carnivores (polar and other bears, mountain lions, coyotes, etc.)

   Marine mammals (porpoises and young whales, etc.)

   Rodents (prairie dogs, squirrels, domestic rats, nutrias, etc.)

2. Raptors (large birds of prey, hawks, eagles, vultures, owls, etc.)

   Cattle

   Billfish (as prototype for other species, e.g., tunas, etc.)

   Deer (as prototype for other hoofed stock, e.g., antelope, caribou)

   Sheep (domestic and mountain, as prototypes for other species)

   Marine turtles

3. Adult whales

4. Pinnipeds (walruses, sea lions, fur seals, etc.)

5. Schooling fish (salmon, anchovies, manhaden)

6. Passerine birds (songbirds and perching birds)

   Shellfish

7.

7. Locusts (as prototypes for insects)

Shellfish (priority 6) and locusts (priority 7) were dropped from further consideration at this time.

Appendix F consists of tables showing the range, resolution and frequency of coverage needed for each datum in order to obtain the information described in this chapter:

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- censusing
- location
- behavior patterns
- relevant physicological factors

Censusing was given top priority by USERs because their entire management plans depend on knowing the size of the population and its dynamics, i.e., numbers, sex ratio and age classes, geographic range and dispersal patterns of component groups over the range.

Censusing of wild animals poses particular difficulties; problems are unique to each species and sometimes to populations within species. Birds are probably better known than most animals because of wide public interest in keeping counts during all stages of birds' travels. Even so, the accuracy is inadequate for management purposes.

Breeding bird surveys are sponsored by the Bureau of Sport Fisheries and Wildlife, the National Audubon Society and other organizations on 1,800 - 50 mile routes distributed throughout the U.S. These surveys rely on trained observers identifying all birds heard or seen at prescribed spots during a prescribed time.

For some species of diving ducks, geese, swans and also large herbivores, substantial percentages of subpopulations often winter in closely packed flocks. In such cases aerial photography, and sometimes estimates by experienced observers in aircraft, are used. Another technique is banding, with mortality figures determined by band return from birds or whales killed by hunters. Indirect means are often necessary. In some cases population levels of animals are inferred by determining the total area of a favorable breeding habitat, and then, through random sampling of these areas, the number of breeding pairs per unit area is determined. All of these methods have obvious limitations.

Catch records of commercial, schooling fish probably provide fairly accurate estimates of populations, but these are not sufficient for regulatory purposes. There are no such records for non-commercial and sport fish or those like tuna which are caught on hand lines.

Present censusing techniques for large mammals rely on traditional personal observation and relatively low altitude aircraft, visual counting and photography. These methods are extremely time consuming and expensive and are not applicable to animals which burrow or which live in forests, caves, underwater or among large rocks.

Effective management of grazing animals such as wild and domestic cattle, sheep and deer requires information on an animal's physiological and behavioral responses to normal growth cycles of vegetation, as well as to various perturbations such as fire, overgrazing, cultivation and other alterations and to varying water regimes. Habitat management further requires information on the responses of vegetation, soil, etc., to animals, for example, the impact of different intensities and durations of grazing or browsing.

Migratory animals which travel considerable distances in remote terrain, such as whales, marine turtles, caribou and antelope, pose particular problems of location, census and general ecological information which are not associated with more sedentary animals.

Predators are more difficult to monitor than grazing herds because they occur in smaller populations and their patterns of activity are more erratic. They may remain in the open when hunting but usually retire to dens and lairs during resting or breeding periods.

Marine mammals pose still other problems, although those that come ashore for breeding (walruses, seals, etc.) may be counted by the same censusing techniques used for migratory waterfowl. For those that remain in the open ocean, some unique and rather challenging problems or correlation between data obtained by aircraft or satellite and actual situations in the sea exist. In counting whales, for example, one needs to know how many animals are below the surface and inaccessible to counting in relation to those counted in order to know the total population.

It was concluded that censusing, although of admittedly great importance, was not a problem susceptible to a simple technological solution until a better analysis of the parameters of the problem cound be worked out. Techniques presently in use — tagging, aircraft, radar, special cameras, radio-telemetry — will have to be relied on for the present and may eventually serve as relays to a satellite in a total surveillance system. A special survey and analysis of available and potential methods of using aerospace technology for censusing should be made, and all avenues of approach to this problem should be explored.

Position/location is discussed in Cahpter IV, which also contains a table showing the preferred systems for each animal category.

Behavior patterns and physiological parameters require direct sensing and microminiaturization of the platform-carried instruments. These are discussed in Cahpter IV as well.

Animal Handling

In handling experimental laboratory or wild animals there are two basic principles to be followed at all times: handling must be 1) lawful and 2) in accord with those practices and procedures established to insure the integrity of behavior and survival of animal subjects. (Refs. Animal Welfare Act of 1966 and 1970). It is mandatory that a licensed veterinarian supervise techniques and procedures conducted on animals in this activity.

Traumatic Effects and Behavioral Alteration

In order to insure valid data, proposed projects should include measures designed to establish "normal" or baseline conditions in order to berable to measure the effect of instrumentation attached or implanted on an animal subject. Such effects may be low level, chronic or acute, immediate or delayed, induced by the stress of capture or attachment procedures. The presence of the instrumentation may subtly interfere with feeding, impair the animal's ability to evade predators, focus the attention of predators on the instrumented animal,or, in colonial animals, affect its social "status" or cause other disruptions of the ecosystem. Non-ionizing raditions (e.g., from radars at a distance or from telemetry in or on the animal have so far shown little effect on laboratory animals; however, data concerning the effects of high-powered radars are not available and should be acquired.

CHAPTER IV

NEEDED TECHNOLOGIES

Technology developed by NASA up to this time is impressive. It is important to point out, however, the extreme difficulty of what is now being proposed. The breadth and scope of the biological and ecological information required and the exceedingly difficult constraints imposed by animals and their behavior make application of NASA's technology to wildlife monitoring a very challenging task.

Over the past decade earth orbiting satellites have proven their value for acquiring quantitative data related to the earth and its environs. Significant technological developments have been accomplished in remote sensing and direct sensing capability. Tracking and data collection systems using radio communications on a global scale have been used to monitor remote unattended sensing devices. For animal tracking, position/location techniques based on animal-to=satellite measurements of range, doppler or through relay of navigational signals (e.g., Omega, Transit) have been considered. For stationary animals, physicological sensor readings can be made daily or hourly from local or remote areas.

Development of these systems began in NASA in the 1960's. A constant NASA goal has been to devise techniques which could be used to meet broad needs, including those of organizations involved with wildlife monitoring. Thus technology has been evolved in various satellite systems for purposes which are different (e.g., ship location) but which have similar requirements (e.g., animal location). These multiple use technological advances offer USERs a variety of hardware to meet their specific needs.

Physiological and Behavioral Sensors

In studies of the physiology and behavior of animals and environmental impacts on them, data which are needed include the following:

Metabolic rate

Heart beat rate

E.E.G

Amount and rate of oxygen consumption

Body temperature, external and internal

Amount of intake and output of water

Estrus or pregnancy status

These data can best be obtained by sensors implanted in the animal or carried on its surface. Past NASA developments as well as dynamic efforts by medical engineers have produced a number of devices and sensor systems potentially appropriate for application to the wildlife program.

The following chart shows the status of application and development of the sensors:

	Applicable Now	Available in 2 Years	Future
Physiological:	Temperature	EEG	pH
	Heart rate	EKG	Gas tensions
	Blood pressure	Blood flow	Enzymes
			Pollutant absorption
			Voiding
			Pregnancy
Behavioral:	Simple physical activity	Heart load	Complete activity
	Orientation	Selective activity	Food/water intake
		Phonation	
		Feeding events	

Many of the parameters listed are interrelated, and the value of one parameter can often be inferred from other information. For example, knowledge of the surfacing of a porpoise gives a very close indication of respiration. Respiration can also be inferred from detailed heart rate information in many species.

Technology Needed for Habitat Information

The reciprocal influences of wildlife and their habitats are of basic importance to wildlife management. Establishment of the carrying capacity of an area will depend not only on the degree of activity of wildlife but equally on the area's productivity. Habitat characteristics must, therefore, be monitored on a continuous basis to permit assessment of wildlife habitat interaction.

ERTS-like multispectral scanning will provide habitat data. However, ancillary data to provide ground truth improve the reliability of data and assist in interpretation of findings. Telemetry from ancillary systems is essential, moreover, in obtaining localized information on a real-time basis for incorporation into a larger, regional surveillance pciture. Data needed include:

- Vegetation type
- Extent and depth of water
- Wind speed and direction
- Air and water temperatures and other meteorological measurements
- Incident light, its character, intensity, periodicity and distribution

Ice and snow distribution

Appendix F provides a full list of the requirements for habitat study.

Technology Needed for Censusing

Censusing, as discussed earlier, is a particularly difficult problem because of the enormous variety of factors involved. Some animals are generally in small groups, others in large herds or flocks. Some are active in the daytime, others at night. Behavior changes with the stages in an animal's development. Again, the use of ancillary systems in conjunction with satellite surveillance is likely to be the most effective for obtaining the required counts.

In general program of monitoring marine animals, a network of ocean buoys serves as an ideal example of an ancillary data system. In essence it serves as an interface between an aerospace system providing position and/or data relay and the surface and subsurface environment. The functions that a buoy or network of buoys would provide are as follows:

A platform from which environmental data (habitat) could be gathered;

A platform for subsurface monitoring (for example, an array of or single hydrophone for detection of the passage of acoustically tagged pelagic fish — tuna, sharks;

A platform for automatic receiving equipment for radio-tagged marine mammals where satellite systems available do not have compatible time coverage (passes are too infrequent or too short);

Temporary storage of acquired data for relay by satellite to shore stations.

Much of the required buoy and buoy-mounted sensor technology is available. The only engineering requirement is the interface between existing oceanographic data-gathering buoy designs with the appropriate acoustic or radio monitoring equipment. Directional acoustic and radio monitoring equipment exist. In the case of the radio receiver, interface equipment is commercially available to provide digital bearing information to the data system. A terrestrial equivalent provides many of the same functions.

Use of tethered balloons employing radio frequency receivers, power systems, distance measuring equipment and angle measurement detectors can provide a substantial increase in animal tracking coverage over that employed by conventional ground-based equipment. Tethered balloons have been employed at altitudes of greater than 3,000 meters for periods of weeks during wartime operations and space physics experiments. Use of balloons for tracking marine life, such as the green turtles which travel 2,400 km in the Atlantic Ocean, may, however, prove not to be feasible due to the absence of land masses for balloon tethering. Tethered balloons may also be restricted in use where they may create aircraft traffic control hazards.

Balloon tethering technology may be expected to improve to permit a doubling of the permissible altitude and a quadrupling of the range of animal tracking. If required, tracking and sensor data received at a balloon could be transmitted to a communications-type satellite for relay to a data processing station located at a point distant from the region of the experiment.

Accurate and high speed systems combining NASA and NOAA systems can give real-time data to monitoring stations in re ote and hostile regions where fish populations are being managed on a day to day basis. Present NOAA techniques involve the use of an acoustic buoy hard-lined to a ship. The buoy counts all fish that pass through it sonar field and transmits the data to the ship.

NASA has designed a system that utilizes a similar buoy which relays the count data from a scan to a shore-based station. Data are then relayed to a compu ation center via a communications relay satellite and back to the fishery management station where catch and escapement rates can be determined. Turnaround times must be short (24 hours) in order to produce the maximum cost/benefit to the USER community.

Technology Needed for Position/Location

In order to obtain the i ormation needed for studies of the physiology, behavi habitat and censusing of wildlife, the subjects first must be located and their movements tracked. The movements of animals as individuals and as population units (herds, flocks, pods) are particularly significant.

Both random and ordered systems are available for position/location in the NASA armamentarium. In addition, a variety of orbital arrangements are possible. Table 2 represents a tabulation of priority-ordered animals with required position/location resolution matched with appropriate aerospace systems.

Where real-time or near real-time (hourly) data are needed, a synchronous satellite is most suitable. Polar orbiting satellites would be used for animals living above 70° S latitude and where the power, size and weight on the animal are critical (because of reduced path losses). (Geostationary systems are also usable in these cases if low duty cycle timers are used to reduce energy requirements.) Polar orbiting satellites are also appropriate when daily or less frequent readings are required. A geostationary satellite is especially suitable for marine animals since only this sytem allows data to be fathered whenever the animal happens to come to the surface.

TABLE 2: SELECTION FOR POSITION/LOCATION

Typical Animal	Priority	Accuracy Needed Position/Location	Preferred Orbit: Low Polar	Preferred Orbit: Geostationary	Applicable System(s): SATELLITE: Doppler (RAMS)	Applicable System(s): SATELLITE: Ranging (IRLS)	Applicable System(s): SATELLITE: Omega/OPLE	Applicable System(s): Ancillary Ground Network
Small whales	1	± 1 - 5 km		x		x	x	x
Porpoises	1	± 1 km		x		x	x	
Waterfowl	1	± 2 - 2.5 km	x	x	x	x	x	
Rodents	1	± 0.5 km	x		x		x	x
Polar and other bears	1	± 1 - 5 km	x		x		x	
Predatory carnivores	1	± 0.5 km	x		x	x	x	x
Bill fish	2	± 10 km	x	x	x	x	x	
Deer (caribou, buffalo, antelope)	2	300 - 500 m		x	x	x	x	x
Marine turtles	2	0.5 - 3 km	x	x	x	x	x	
Sheep, mountain and domestic	2	0.5 km	N/A	N/A			x	x
Cattle	2	300 m	N/A	N/A			x	x
Large whales	3	± 5 km		x		x	x	
Pinnipeds	4	3 - 5 km		x	x	x	x	x
Salmon	5	1 km	x	x			x	x
Passerines	6	± 1 km	x	x	x	x	x	

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Doppler (RAMS)

The RAMS (Random Access Measurement System) is a new space technology concept for tracking of and data transmission from moving platforms. It uses a non-ordered (no interrogation required) method which eliminates the need for a receiver on the animal and greatly reduces power, weight and volume requirements of electronic gear. RAMS experimentation will be conducted on the Nimbus-F satellite in mid-1974 and, if successful, will be included in future TIROS operational satellites. Additional USER systems development can further reduce the weight and size of the RAMS electronics applicable to a wide variety of wildlife. (RAMS characteristics are presented in Appendix F.)

Ranging (IRLS)

The Interrogation Recording and Location System is an ordered system requiring a receiver and transmitter. It has operated successfully in conjunction with the Nimbus 3 and 4 satellites to track moving platforms, including the only satellite-tracked animal to date, an elk. This now proven concept requires additional miniaturization efforts to reduce the size and weight of the tracking hardware. An animal's position/location and the readout of its sensor data can occur at least once daily and usually more often employing the IRLS/Nimbus system. (IRLS characteristics are presented in Appendix F.)

Omega-OPLE

The Omega-OPLE system (Omega Position Location Experiment) could be applied in some cases where animals are traversing relatively short distances and their starting point is well-known. There are potential problems with multiple antennae on the animal, highly miniaturized VLF (very low frequency) antennae, complexity of the animal pack and eventual development of techniques for simplified localization. With substantial successful development effort Omega-OPLE has potential for broad application. Omega-OPLE is further described in Appendix F.

Ancillary Ground Network

Numerous ground-based tracking systems have been successfully employed to locate wildlife and could be used with modifications for other technological functions. Tethered balloons have flown at altitudes o. up to 3,000 meters. With proper telecommunication-type equipment, these balloons could significantly extend the tracking range of animals carrying presently used equipment.

Large terrestrial radars have, to a limited degree, been employed to track flocks of insects, birds and bats. The resulting information provides density estimates of a flock. The use of surveillance radar for application to transponder-equipped animals is in the research stage and experimentation is required.

Existing radio direction finding systems consist of animal-carried transmitters emitting signals which permit range and bearing angles to be determined at the receiving station. The tracking range is limited due to the radio frequencies employed. Greater tracking range is limited due to the radio frequencies employed. Greater tracking ranges are possible with systems operating at lower radio frequencies, but additional effort on smaller antennae is required.

Most of the ground-based tracking techniques for animals are applicable to short migration routes (less than 160 km) and are susceptible to radio atmospheric disturbances. Their successful operation, low cost and light weight make them desirable where appropriate. Further descriptions of ancillary ground systems are presented in Appendix F.

As analysis of Table 2 indicates an almost equal preference for the low orbit polar satellite and the geostationary satellite. Following are explanations for the stated preferences:

Small Whales and Porpoises

The OMEGA/OPLE system on a geostationary satellite is preferred here because these animals surface frequently to breathe and are at the surface long enough for an ordered system to be effective.

Waterfowl

Both an ordered and a random-type system on low orbit polar and geostationary satellites are applicable; worldwide coverage is necessary for these animals. The simplest animal pack probably is the RAMS unit, from the viewpoint of ultimate weight, size minimization and worldwide coverage. RAMS is also economical.

On the other hand, when long term studies are involved, enormous savings in battery weight will accrue in the use of an ordered system because of sharp improvements in duty cycle.

Rodents

These have severe size and weight limitations but a relaxed frequency of coverage requirement. Ancillary ground networks will be useful because of the burrowing behavior of the rodents. The RAMS system appears appropriate.

Polar and other Bears

Frequency of coverage requirements and the availability of many passes per day over the arctic habitat make the RAMS system appropriate.

Predatory Carnivores

Low frequency of coverage requirements and wide spatial distribution dictate a RAMS system.

Billfish/tuna

These animals rarely surface, and position/location data can be obtained only by the use of ancillary equipment such as releasable, expendable transmitters. In this case either the RAMS or the Omega/OPLE systems are appropriate.

Deer (etc.)

The Omega/OPLE system is preferred. Almost certainly ancillary ground networks will be used with these animals for collection of large amounts of data.

Marine turtles

See Billfish/Tuna

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Large whales

Although these animals do not surface as frequently as small whales, when they do, they are available for at least several seconds. Further, because of the difficulty in placing equipment on animals of this size, the maximum amount of gear must be included in the smallest possible package. The RAMS system is preferred, but Omega/OPLE can be used advantageously.

Pinnipeds

May involve the use of ancillary ground networks; see Deer.

Salmon

Either the RAMS or Omega/OPLE systems are appropriate. Data also may be accumulated by ancillary ground networks.

Passerines

See Waterfowl.

The RAMS system has potential for immediate as well as future use with many of the animals listed. Tacit in this statement is that frequency of coverage will be limited to satellite overpass varying from once or twice per 24 hours to many passes as a function of latitude. Frequency of coverage can be improved with ancillary ground networks and/or recoverable data recorders as appropriate. The simplicity of the RAMS system is important because such a system can be put into the field early, and valuable wildlife resource data can be made available without excessive delay. However, for more sophisticated data collection, more advanced systems will be necessary.

The Omega/OPLE system pormises long-term applicability for all animals listed -- assuming that system development can be carried to the point where non-ambiguous localization is possible and microminiaturization is accomplished.

Microminiatruization

Basic to practical considerations related to acquisition of position/ location information plus other pertinent data is the attachment of a platform to the animal being studied.

The attachment of any foreign object to an animal must be done with care so as not to introduce a physiologically or behaviorally unacceptable variant. As a matter of hard fact, such aberrations will act to degrade the value of any data acquired.

These difficulties, which vary from species to species, can be sharply reduced by microminiatruization of gear to be attached to the animal. We can conclude with ample justification that the smaller the year, the greater the number of species to which it can be effectively applied.

Accordingly, microminiaturization was based on bird requirements. Two typical sizes of birds were selected: fairly large sized waterfowl (ducks, geese, swans) and raptors (large predator birds), and small passerines.

The transmitter power, life, size and weight of the packages are critical factors. Typical weight allowances are:

Waterfowl and Raptors	Passerines
100 - 200 grams	10 grams

When considering monitoring applications for systems such as those of Nimbus-F (RAMS) and TIROS-N, it is estimated that electronics units manufactured under normal assembly techniques could be produced in the 200 gram class. Miniatruization could achieve 80 grams in a 28 cc. volume in the immediate future without major effort. A subsequent step in microminiaturization can be expected to reduce this to 12 grams in about 2 cc. Estimates of battery and antenna weights to be added to the above run from 40 to 1,000 grams depending upon communication requirements. (Total weight range is now 52 to 1,200 grams).

If a synchronous two-satellite ranging system were used, a standard assembly miniaturized receiver would add approximately 160 grams. (Total weight range is now 340 - 1,360 grams). Microminiaturization must be applied to further reduce this weight.

Power sources of greater efficiency could significantly reduce the weights estimated above. Lithium-fluoride cells are becoming available and promise a 2.5 to 1 improvement in efficiency over nickel-cadmium cells. Tests of these cells are planned under the Goddard Space Flight Center Carrier Balloon System for Global Atmosphere Program Research, where expendable dropsondes are being developed. Solar cells application and further improvement in battery efficiencies must be explored. (Total weight range is 32 - 680 grams).

Low power, stable master oscillators are most critical and will require temperature stabilization. The next item of priority is the radio frequency multiplier-transmitter chain. The existing state of the art in digital, low power circuitry is acceptable and needs no further research and development for use here.

There would be a non-recurring cost for design and layout of the total package, but this work should be delayed until master oscillator and radio frequency modules are completed.

New technology leading to reduced size of antennae has been developed over past years using "loading" techniques with various di-electrics. Such antennae require additional power because of inefficiencies caused by impedance mismatch. Further research and development into such antennae is not practical or beneficial. Platform designs will be based upon use of standard ¼ wave monopoles which consist simply of short length wires (20 cm at UHF) and a "ground plane" of metal mesh or wires.

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CHAPTER V

PUBLIC RELATIONS

The public relations aspect of the wildlife monitoring program focuses around two areas: the solicitation of input and critiquing by public and private organizations who are or might be involved with wildlife resources; and the issue of animal handling.

Public and Private Support

Solicitation of cooperation has already occurred. Every organization identifiable that would potentially be interested in the program was contacted and asked for suggestions and comments and additions to the material sent them.

Response to the program indicated that the projects are both necessary and relevant.

Animal Handling

Experience has shown that public relations in this program will be delicate. Proposed projects involve the handling of many species, some rare and endangered, others for which people have strong emotional feelings. The death of a single animal involved in the program, regardless of statistical proof that a certain portion of a wild population is always in the process of dying, could result in serious criticism of NASA.

The major conservation organizations should be solicited for positive support and kept informed of all program activities.

Some groups will be dogmatic in their rejection of the handling of animals for any reason; they should be identified early so that the USERs and NASA can be ready with acceptable explanations of the studies being undertaken. It should be clearly point out that for wildlife monitoring to be effective, all animals will be treated so that they live and be! naturally. A dead or injured animal would be of no use to the prog It is in the utmost interest of scientists that the greatest care be taken with the subject animals.

Another innovative approach to public relations might be to set up a real-time (or almost so) display of the world showing the present location of selected animals being tracked. This display (more than one if the system turned out to be relatively inexpensive) could be located at highly visible locations such as the Smithsonian Institution, Bronx Zoo, American Museum of Natural History, etc. The possibility of using schools and colleges should also be explored.

NASA should stress emphatically that the purposes for monitoring wildlife are positive, represent a direct response to national goals as established by law and will contribute to conservation of our living resources.

An excellent set of principles of humane and "good science" animal handling is presented in Appendix G.

CHAPTER VI

USER-NASA COOPERATION COLLABORATION AND COORDINATION

The success of a national wildlife resources monitoring program will depend very largely on NASA's ability to enlist the interest and active support of USERs — federal, state and private. The following steps need to be considered to achieve this cooperation.

Communications and Coordination

From its very inception the wildlife resources monitoring program plan has been designed in response to expressed needs of USER agencies. A well balanced and comprehensive national program of wildlife resources monitoring must, however, respond both to the specific information needs of identified agencies and to the information needed to achieve certain national goals which may extend beyond the current responsibilities of individual agencies.

Planning for Active Collaboration among Federal Agencies

This program cannot evolve if based only on expressions of general interest. USER agencies must commit themselves to financial collaboration in support of the program, preferably at an early stage. At the very least USER agencies must show their intent by inserting specific line items in their respective appropriations requests to Congress.

Planning for Active Collaboration with State Agencies

In a major way a national wildlife resources monitoring program will provide the information needed by state USER agencies.

The question of financial collaboration must be left open for the present. Participation by state scientific and technical personnel in program planning and implementation should be addressed and encouraged.

Planning for Active Collaboration with Non-governmental USERs

The degree of success of some past national science and technology programs can be directly correlated with the amount and quality of collaboration attained with non-governmental sectors, particularly during the early stages of program planning. The same correlation would appear likely for the national wildlife resources monitoring program, with one major addition. Federal and state agency USERs will probably make the principle immediate contributions to improving wildlife resources management as a result of the monitoring program. In the long run, however, the major additions to man's knowledge about relationships among wilflife resources and global life support systems will come from the non-governmental sector's use of monitoring information on wildlife resources. Traditionally, private and academic institutions have been in a better position to attack long-term fundamental problems. Governmental contributions are generally designed to achieve more discreetly defined short-term goals related to agency missions. Therefore, the governmental sector must collaborate with non-governmental sectors during all phases of policy formulation and program planning. The need for participation by representatives of the private, academic, conservationist and industrial communities is obvious, and its importance warrants sp[illegible] [illegible]asis.

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NASA's Role

The enviornment has become a subject uppermost in the concern of the public and government. Both science and technology are advancing rapidly, and NASA has thus far contributed substantially to this advance. Its entrance into the wildlife monitoring program would be wasteful if it were to be for a short term. A continuing program of science, research and technology to keep abreast of rapidly expanding requirements of monitoring is essential if NASA is to keep in the forefront of the field. NASA must begin as soon as possible to enter upon this urgent program on which so many organizations depend. The interim research and development program, in fact, must be continued in order to maintain the momentum gained in saving time and dollars in the long run.

Appendix B: List of Organizations and Participants Cooperating in the Wildlife Monitoring Program

Part I: Federal Agencies and States

Part II: Private Organizations

Part III: Participants in the Wildlife Monitoring Program Planning Meetings

Part I: Federal Agencies and States

Among the Federal agencies represented in the preparation of this report were the:

Atomic Energy Commission

Council on Environmental Quality

Department of Agriculture (Forest Service, Agricultural Research Service)

Department of Commerce (Office of the Assistant Secretary of Science and Technology [Environmental Affairs], National Oceanic and Atmospheric Administration, National Marine Fisheries Service)

Department of Defense (Air Force, Army Corps of Engineers, Navy)

Department of Health, Education and Welfare (Public Health Service)

Department of State

Department of the Interior

Department of Transportation (Coast Guard, Federal Aviation Agency)

Environmental Protection Agency

National Aeronautics and Space Administration

National Science Foundation

Smithsonian Institution

States responding were:

Alabama	Colorado
Arizona	Connecticut
Arkansas	Delaware
California	Florida

Georgia

Hawaii

Idaho

Illinois

Indiana

Iowa

Kansas

Kentucky

Louisiana

Maine

Maryland

Massachusetts

Michigan

Minnesota

Mississippi

Missouri

Montana

Nebraska

Nevada

New Hampshire

New Jersey

New York

North Carolina

North Dakota

Ohio

Oregon

Pennsylvania

South Carolina

South Dakota

Tennessee

Utah

Washington

West Virginia

Wisconsin

Wyoming

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Part II: Private Organizations

The entire membership (listed below) of the Natural Resources Council of America has received information about the program, and their comments have been actively solicited:

American Committee for International Wild Life Protection, Washington, D.C.

American Fisheries Society, Washington, D.C.

American Forestry Association, Washington, D.C.

American Institute of Biological Sciences, Inc., Washington, D.C.

American Littoral Society, Sandy Hook, Highlands, New Jersey

American Scenic and Historic Preservation Society, Pelham, New York

American Society of Landscape Architects, McLean, Virginia

American Water Resources Association, Arlington, Virginia

Appalachian Mountain Club, Lincoln Center, Massachusetts

Association of Interpretive Naturalists, Derwood, Maryland

Boone and Crockett Club, Chicago, Illinois

Boy Scouts of America, New Brunswick, New Jersey

Camp Fire Club of America, Chappaqua, New York

Conservation Education Association, Jefferson City, Missouri

The Conservation Foundation, Washington, D.C.

J. N. "Ding" Darling Foundation, Des Moines, Iowa

Ecological Society of America, University of North Carolina, Chapel Hill, North Carolina

Federation of Western Outdoor Clubs, Seattle, Washington

Forest History Society, Inc., Santa Cruz, California

Friends of the Earth, San Francisco, California

International Association of Game, Fish and Conservation Commissioners, Washington, D.C.

Izaak Walton League of America, Arlington, Virginia

League of Women Voters of the United States, Green Bay, Wisconsin

National Association of Conservation Districts, Washington, D.C.

National Association of State Foresters, Department of Natural & Economic Resources, Raleigh, North Carolina

National Audubon Society, New York, New York

National Recreation and Park Association, Arlington, Virginia

National Rifle Association of America, Washington, D.C.

National Wildlife Federation, Washington, D.C.

The Nature Conservancy, Arlington, Virginia

North American Wildlife Foundation, Washington, D.C.

Sierra Club, San Francisco, California

Society of American Foresters, Washington, D.C.

Society for Range Management, Denver, Colorado

Soil Conservation Society of America, Ankeny, Iowa

Sport Fishing Institute, Washington, D.C.

Trout Unlimited, Denver, Colorado

The Wilderness Society, Washington, D.C.

The Wildlife Society, Washington, D.C.

Wildlife Management Institute, Washington, D.C.

World Wildlife Fund, Washington, D.C.

Specific responses, all favorable, have been received from:

American Forestry Association

Association of Interpretive Naturalists

International Union for the Conservation of Nature and Natural Resources

Montana Cooperative Wildlife Research Unit

National Association of State Foresters

National Audubon Society

National Rifle Association

National Wildlife Federation

Society for Range Management

The Wildlife Society

Wildlife Management Institute

Part III: Participants in the Wildlife Monitoring Program Planning Meetings

PREPLANNING SESSION

for

SUMMER CONFERENCE ON WILDLIFE MONITORING

NASA Headquarters - December 12, 1972

Participants:

Sidney R. Galler,	Department of Commerce (Chairman)
Helmut K. Buechner,	National Zoological Park
John Bushman,	Corps of Engineers, Department of Defense
Bill Caldwell,	Office of Science and Technology
John Fiebelkorn,	NASA
George J. Jacobs,	HQ/Earth Resources, NASA
R. F. Melsheimer,	Coast Guard, Department of Transportation
Robert H. Miller,	Agricultural Research Service, Department of Agriculture
John Ted Mock,	Science Advisor to the Governor of Georgia
Jack Posner,	HQ/USER Affairs, NASA
Georald W. Sharp,	National Aeronautics and Space Council
Dixie R. Smith,	Forest Service; Department of Agriculture
Mike Toohey,	Corps of Engineers, Department of Defense
Billy J. Van Tries,	Bureau of Sport Fisheries and Wildlife, Department of the Interior
F. G. Wood,	Naval Undersea Center, Department of Defense

WILDLIFE CONFERENCE - USERS GROUP MEETING

NASA Headquarters - February 14, 1973

Participants:

Gerald Bertrand,	Council on Environmental Quality
Helmut K. Buechner,	National Zoological Park
John Bushman,	Corps of Engineers, Department of Defense
John H. Busser,	American Institute of Biological Sciences
Bill Caldwell,	Office of Science and Technology
William E. Evans,	National Marine Fisheries Service, Department of Commerce; LaJolla, California
John T. Everett,	National Marine Fisheries Service, Department of Commerce; Washington, D.C.
Robert M. Goodman,	Franklin Institute Research Laboratories
George J. Jacobs,	HQ/Earth Resources, NASA
Duncan MacDonald,	Bureau of Sport Fisheries and Wildlife, Department of the Interior
Robert H. Miller,	Agricultural Research Service, Department of Agriculture
John Ted Mock,	Science Advisor to the Governor of Georgia
David Penick,	Office of the Chief of Engineers, Department of Defense
Jack Posner,	HQ/User Affairs, NASA
Dixie R. Smith,	Forest Service, Department of Agriculture
John W. Tremor,	NASA - Ames Reserach Center

NASA/AIBS SANTA CLARA CONFERENCE ON WILDLIFE MONITORING IN RESPONSE TO NATIONAL NEEDS

Ad Hoc Panel

Ames Research Center - April 24-27, 1973

Participants:

Robert M. Goodman,	Franklin Institute Research Laboratories Philadelphia, Pennsylvania, (Chairman)
Howard A. Baldwin,	Los Alamos Scientific Laboratory; Los Alamos, New Mexico
Gerald Bertrand,	Council on Environmental Quality; Washington, D.C.
Helmut K. Buechner,	National Zoological Park; Washington, D.C.
John H. Busser,	American Institute of Biological Sciences; Washington, D.C.
Archie F. Carr,	University of Florida; Gainesville, Florida
Bruce Collette,	Smithsonian Institution; Washington, D.C.
Charles Cote,	NASA-Goddard Space Flight Center; Greenbelt, Maryland
Frank C. Craighead, Jr.,	Environmental Research Institute; Moose, Wyoming
John Craighead,	University of Montana; Missoula, Montana
Albert Erickson,	University of Idaho; Moscow, Idado
William E. Evans,	National Marine Fisheries Service; La Jolla, California
John T. Everett,	National Marine Fisheries Service; Washington, D.C.
Harvey Fisher,	Southern Illinois University; Carbondale, Illinois

Thomas B. Fryer,	NASA-Ames Research Center; Moffett Field, California
George J. Jacobs,	HQ/Earth Resources, NASA; Washington, D.C.
Dale K. Kratzer,	Applied Information Industries; Moorestown, New Jersey
Jack W. Lentfer,	Bureau of Sport Fisheries and Wildlife; Department of the Interior, Anchorage Alaska
Nathan Liskov,	Raytheon Company; Raylond, Massachusetts
Maurice W. Long,	George Institute of Technology; Atlanta, Georgia
R. Stuart Mackay,	Boston University; Boston, Massachusetts
Joseph Margolin,	Applied Information Industries; Moorestown, New Jersey
Hugh Martin,	Ocean Applied Research Corporation; San Diego, California
Kenneth S. Norris,	University of California; Santa Cruz, California
G. Carleton Ray,	Johns Hopkins University; Baltimore, Maryland
Samuel Ridgeway,	Naval Undersea Center; San Diego, California
Paul Sebesta,	NASA - Ames Research Center; Moffett Field, California
Richard Simmonds,	Johnson Space Center; Houston, Texas
William Sladen,	Johns Hopkins University; Baltimore, Maryland
William H. Stevenson,	National Marine Fisheries Service; Bay St. Louis, Mississippi
Billy J. Van Tries,	Bureau of Sport Fisheries and Wildlife; Department of the Interior, Washington, D.C.
Joel Varney,	University of Montana; Missoula, Montana
George E. Watson,	Smithsonian Institution; Washington, D.C.
Janet Williams,	State University of New York; Buffalo, New York
T. C. Williams,	State University of New York; Buffalo, New York

WRITING CONFERENCE ON WILDLIFE MONITORING

Santa Cruz - September 5-9, 1973

Participants:

John Billingham,	NASA - Ames Research Center; Moffett Field, California
John H. Busser,	American Institute of Biological Sciences; Washington, D.C.
Charles Cote,	NASA-Goddard Space Flight Center; Greenbelt, Maryland
Jerry M. Deerwester,	NASA - Ames Research Center; Moffett Field, California
Eugene Ehrlich,	NASA, Washington, D.C.
Sidney R. Galler,	Deputy Assistant Secretary for Environmental Affairs, Department of Commerce; Washington, D.C.
Robert M. Goodman,	Franklin Institute Research Laboratories; Philadelphia, Pennsylvania
Helen L. Hayes,	Fact Research Inc.; Washington, D.C.
George J. Jacobs,	NASA, Washington, D.C.
Angeco Paul Margozzi,	NASA - Ames Research Center; Moffett Field, California
Hugh Martin,	Ocean Applied Research Corporation; San Diego, California
Jerry Mensch,	California Department of Fish and Game; Sacramento, California
Kenneth S. Norris,	University of California; Santa Cruz, California
Archibald B. Park,	Earth Satellite Corporation; Washington, D.C.
Orr E. Reynolds,	American Physiological Society Bethesda, Maryland

Paul Sebesta,	NASA - Ames Research Center; Moffett Field, California
Lee M. Talbot,	Council on Environmental Quality; Washington, D.C.
John W. Tremor,	NASA - Ames Research Center; Moffett Field, California
Charles Vaughn,	NASA - Wallops Station; Wallops Island, Virginia
Raymund L. Zwemer,	Federation of American Societies for Experimental Biology; Bethesda, Maryland

Appendix C: International Agreements and Treaties and Federal Laws Relating to Wildlife Management, Conservation and Utilization

Part I: Selected International Agreements and Treaties

Part II: Selected Federal Laws

Part I: Selected International Agreements and Treaties

	Organization or Treaty	Signatories/ Member States	Year	Actions/Excerpts
1.	The Antarctic Treaty	13	1959	"...preservation and conservation of living resources in Antarctica...."
2.	Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere	18	1940	"...to protect and preserve...all species..., including migratory birds, ...to assure them from becoming extinct...'
3.	Interim Convention on the Conservation of North Pacific Fur Seals	4	1957	"...to make possible the maximum sustainable productivity of the fur seals...shall include studies of... size of fur seal herd and its age and sex composition...migration routes of fur seals..."
4.	International Convention for the Conservation of Atlantic Tunas	UN/FAO	1969	"...Conservation of the resources of tuna and tuna-like fishes...study of the population...include research on the abundance, biometry, and ecology..."
5.	International Convention for the Northwest Atlantic Fisheries	12	1950	"...investigation, protection and conservation of the fisheries...investigation into the abundance, life history and ecology of any species of aquatic fish..."
6.	Convention for the Establishment of an Inter-American Tropical Tuna Commission	2	1950	"...maintaining the populations of yellowfin and skipjack tuna.... Make investigations concerning the abundance, biology, biometry and ecology of yellowfin...and skipjack... tuna..."
7.	International Convention for the High Seas Fisheries of the North Pacific Ocean	3	1953	"...to ensure the maximum sustained productivity of the fishery resources... to carry out necessary conservation measures..."
8.	Indo-Pacific Fisheries Council Amended Agreements for Its Establishment	8+ UN/FAO	1958	"...To formulate...biological and other... aspects of...proper utilization of living aquatic resources...To encourage... research and applications of improved methods..."

Organization or Treaty	Signatories/ Member States	Year	Actions/Excerpts
9. Regional Caribbean Fishery Development Project: Plan of Operation of United Nations Special Fund Project on Caribbean Fishing Development	21	1966	"...Exploratory fishing, market study and demonstration.... Such biological... observations...as are considered practicable and desirable..."
10. Final Act of the United Nations Conference on the Law of the Sea: Convention			"...to examine the law of the sea... technical, biological...aspects..."
c. Fishing and Conservation of the Living Resources of the High Seas	16	1966	"...conservation of the living resources of the high seas....Conservation programmes should be formulated..."
11. Convention for the Protection, Preservation and Extension of the Sockeye Salmon Fishery of the Fraser River System	2	1947	"...protection, preservation and extension of the sockeye salmon fishery... investigation into the natural history of the...sockeye salmon..."
Amended		1957	"...coordinated investigation of pink salmon..."
12. Agreement to Facilitate the Ascent of Salmon in Hell's Gate Canyon and Elsewhere in the Fraser River System	2	1944	"...investigation into the natural history of...sockeye salmon..."
13. Convention for the Preservation of the Halibut Fishing of the Northern Pacific Ocean and Bering Sea	2	1953	"...preservation of the halibut fishery... to determine the condition and trend of the halibut fishery..."
14. Convention on Great Lakes Fisheries	2	1954	"...conduct investigations...[for maximum sustained productivity]"
15. Convention for the Protection of Migratory Birds	2	1916	"...an effective means of preserving migratory birds..."
16. Convention for the Protection of Migratory Birds and Game Mammals	2	1937	"...to employ adequate measures which will permit a rational utilization of migratory birds for...sport as well as food, commerce and industry..."

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Organization or Treaty	Signatories/ Member States	Year	Actions/Excerpts
17. Agreement Regarding Fisheries in the Western Region of the Middle Atlantic Ocean, with Exchange of Letters	2	1969	"...the need for widening and coordinating scientific research in the field of fisheries..."
18. Agreement on Certain Fishery Problems on the High Seas in the Western Area of the Middle Atlantic Ocean	2	1969	"...to conduct the fisheries...with due consideration of the state of the fish stocks based on the results of scientific investigation...to expand research pertaining to the species of fish of interest..."
Agreements not yet ratified by U.S.A.			
19. Convention for the International Council for the Exploration of the Sea (CR, March 1, 1967, pp. 32860-1)	17		"...to promote and encourage research and investigations for the study of the sea particularly...living resources..."

Part II: Selected Federal Laws

Law	Title or Popular Name	Actions/Excerpts
1. 16 U.S.C. 668aa to 668cc-6	Endangered Species of Fish and Wildlife	(668aa) "...United States has pledged...to conserve and protect...native fish and wildlife..." (668bb) "...carry out a program...of conserving, protecting...selected species of native fish and wildlife...threatened with extinction...." (668cc) "...States...consultation before acquisition of land for...conserving, protecting..." (668cc-3) "A species...shall be deemed to be threatened with...extinction based on the best scientific and commercial data available..." (668cc-5) "Encouragement of programs of foreign countries;...conservation practices...in international trade."
2. 16 U.S.C. 655-656	Management of Seals in Alaska	(655) "The Secretary of the Treasury is authorized to appoint one agent and...who shall be charged with the management of the seal fisheries..."
3. 16 U.S.C. 742(a)-754	Fish and Wildlife Service	(742d-1) "...undertake...studies on the effects of insecticides,...pesticides upon the fish and wildlife resources..."
4. 16 U.S.C. 661-667e	Fish and Wildlife Coordination	(661 and 665) "...development, protection...of wildlife...make surveys and investigations of the wildlife...determination of standards of water quality for the maintenance of wildlife...".
5. 16 U.S.C. 460k-460k-4	Recreational Use of Wildlife Areas Administered by the Secretary of the Interior	(460k-1) "...acquire...land...for - (1) fish and wildlife-oriented recreational development, or (2) the protection of natural resources..."
6. 18 U.S.C. 41-44, 47, 1165, 3054, 3112	General Criminal Provisions Relating to Fish and Wildlife	(41) "...willfully disturbs or kills any...wild animal...shall be fined...or imprisoned [except in compliance with rules]..."
7. 19 U.S.C. 1527	Importation of Wild Mammals and Birds	"If the laws...of any county...restrict the taking...possession, or exportation...of any wild mammal or bird...shall be subject to seizure..."

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Law	Title or Popular Name	Actions/Excerpts
8. 16 U.S.C. 581d	Studies of Wildlife in National Forests	"For such experiments...as may be necessary in determining the life histories and habits of... wildlife...and in developing...methods for their management..."
9. 7 U.S.C. 426-426b	Wildlife Control Program	(426) "...to conduct such investigations,...to determine...best methods of...bringing under control...mountain lions, wolves, coyotes... and other animals injurious to agriculture... wild game...and birds...and for the protection of stock..."
10. 16 U.S.C. 668-668d	Protection of Bald and Golden Eagles	(668) "Whoever, ...shall...take, possess, sell... any bald eagles...shall be fined... '...the bald eagle is now threatened with extinction:'..."
11. 16 U.S.C. 1331-1340	Protection of Wild Horses and Burros	(1331) "...wild free-roaming horses and burros shall be protected..."
12. 16 U.S.C. 1361, 1362, 1371-1384, 1401-1407	Marine Mammal Protection	(1361) "...species and population stocks should not be permitted to diminish beyond...functioning element in the ecosystem...efforts...to protect the rookeries,...encourage the development of international...research on, and conservation of, all marine mammals;..."
		(1362) "...collection and application of biological information for the purpose of increasing and maintaining the number of animals within species and populations of marine mammals at the optimum carrying capacity of their habitat...include the entire scope of activities that constitute a modern scientific resource program,...research, census, law enforcement, and habitat acquisition and improvement... periodic or total protection of species or population as well as regulated taking...."
		(1371) "...moratorium on the taking...of marine mammals...except...for purposes of scientific research..."
		(1373) "The Secretary, on the basis of the best scientific evidence available...shall prescribe... regulations..."
		(1375) "Penalties...."
		(1378) "...development of...agreements with other nations for the protection and conservation of all marine mammals..."

Law	Title or Popular Name	Actions/Excerpts
		(1381) "...to...undertake a program of research and development for...improved fishing methods...to reduce...incidental taking of marine mammals..."
		(1402) "...conduct a continuing review of the condition of the stocks of marine mammals, of methods for their protection and conservation,...of research programs conducted...undertake...such...studies as...necessary...to the protection and conservation of marine mammals;..."
13. 16 U.S.C. 668dd-668jj	Administration of National Wildlife Refuge System	(668dd) "For the purpose of consolidating the authorities...Secretary of the Interior for the conservation of fish and wildlife...permit the use of any area...to hunting, fishing, public recreation..."
		(668ff) "...San Francisco Bay...for the protection of...wildlife,...and to provide an opportunity for wildlife-oriented recreation and nature study..."
14. 16 U.S.C. 669-669i	Wildlife Restoration Projects	(669a) "...such research into problems of wildlife management as may be necessary to efficient administration affecting wildlife resources,..."
		(669g) "Maintenance of wildlife-restoration projects...shall be the duty of the States in accordance with their respective laws...."
15. 16 U.S.C. 670a-670f; 10 U.S.C. 2668,2671	Fish and Wildlife Conservation on Military Reservations	(16 U.S.C. 670a) "The Secretary of Defense...to carry out a program of planning, development, maintenance and coordination of wildlife, fish and game conservation...conservation and management of fish and wildlife, including habitat improvement...[on military reservations]"
		(16 U.S.C. 670b) "...program for the conservation,...management of migratory game birds..."
		(16 U.S.C. 670c) "...a program for development,...of public outdoor recreation..."
		(10 U.S.C. 2668) "...Secretary...may grant,...easements for rights-of-way...for -...dams...in connection with fish and wildlife programs,..."
		(10 U.S.C. 2671) "The Secretary of Defense shall,...develop,...in cooperation with the...State...to effect measures for the management, conservation, and harvesting of fish and game resources...."

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Law	Title or Popular Name	Actions/Excerpts
16. 16 U.S.C. 671-697a	Game and Wildlife Preserves	(671) "...reserved...lands...for a permanent National Bison Range...for the proper care and maintenance of ...bison."
		(673 and 673c) "...a winter game (elk) reserve...for the maintenance of the reserve... Wyoming Game and Fish Commission and the National Park Service...joint recommendations for the management...of the elk..."
		(674) "...Sullys Hill National Game Preserves... for the proper care...of the animals and birds therein,...structures necessary for the convenience of visitors..."
		(675) "...Norbeck Wildlife Preserve...for the protection of game animals and birds,..."
		(680) "Game animal and bird refuge in South Dakota...for...protecting...antelope and other game animals and birds:..."
		(682) "...Ozark National Forest...for the protection of game animals, birds, or fish;..."
		(683) "The President of the United States is authorized to designate...areas...purchased by the United States...for the protection of game animals, birds, or fish;..."
		(684) "...Wichita National Forest and in the Grand Canyon National Forest...protection of game animals and birds..."
		(688) "Sequoia National Game Preserve...."
		(689) "Tahquitz National Game Preserve...."
		(690) "Bear River Migratory Bird Refuge;..."
		(691) "Cheyenne Bottoms Migratory Bird Refuge,..."
		(692) "...Ocala National Forest...protection of game animals and birds,..."
		(693) "Game sanctuaries...in Ouachita National For st...."
		(693b) "Robert S. Kerr Memorial Arboretum...to... make available to this and future generations the opportunity to advance...intellectually, and spiritually by learning about nature..."

Law	Title or Popular Name	Actions/Excerpts
		(694) "Fish and game sanctuaries in national forests; establishment by President...."
		(695 and 695b) "Migratory waterfowl and other wildlife refuge in California;...primarily as wildlife management areas..."
		(695k) "...to preserve...existing habitat for migratory waterfowl...and to prevent depredations of...waterfowl on agricultural crops..."
		(695l) "[lands] dedicated to wildlife conservation...but with full consideration to optimum agricultural use...waterfowl management,..."
		(696) "National Key Deer Refuge;...conservation and management of...key deer and other wildlife:..."
17. 16 U.S.C. 701-718h	Protection of Migratory Game and Insectivorous Birds	(701 and 715i) "The duties...of the Department of the Interior include the preservation, distribution,...of game birds and other wild birds....[legal aspects and fines for molesting birds]...to manage timber, range, and agricultural crops; to manage other species of animals, including but not limited to fenced range animals, with the objectives of perpetuating, distributing, and utilizing the resources;..."
18. 16 U.S.C. 721-731	Upper Mississippi River Wild Life and Fish Refuge	(722) "...acquire,...land,...between Rock Island, Illinois, and Wabasha, Minnesota,...for the purposes of...part of the...Refuge..."
		(723) "...refuge and breeding place... [conservation]"
19. U.S.C. 1221-1226	Estuarine Areas	(1221) "...estuaries...rich in...natural, commercial,...resources,...are of...value to... Americans...need to protect, conserve, and restore...estuaries in a manner that...maintains a balance...in the interest of conserving the natural resources..."
20. 7 U.S.C. 426	Predatory Mammal Control Program	"...conduct such investigations, experiments, and tests as...necessary...to...bringing under control...mountain lions, wolves, coyotes, bobcats, prairie dogs,...for the protection of stock through the suppression of rabies and tularemia in predatory or other wild animals..."

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Law	Title or Popular Name	Actions/Excerpts
21. 7 U.S.C. 1010, 1010a	Land Conservation and Utilization by the Secretary of Agriculture to Protect Fish and Wildlife	(1010) "...to develop a program of land conservation and...utilization,...in... preserving natural resources, protecting fish and wildlife,..."
22. 7 U.S.C. 442-446	Waterfowl Depredations Prevention	(442 and 443) "...preventing crop damage by migratory waterfowl,...grain acquired...[to] lure migratory waterfowl away from crop depredations..."
23. 7 U.S.C. 447-449	Surplus Grain for Wildlife	(447) "...emergency situations caused by... weather...destruction of...wildlife resources,... States are authorized,...[to acquire grain for] game birds and other resident wildlife from starvation,..."
24. P.L.81-718 (64 Stat. 465)	Back Bay National Wildlife Refuge	"...granting...road...through the wildlife refuge...[tolls] sums...credited to the migratory bird conservation fund..."
25. 16 U.S.C. 459f-5(a), (b) and 459f-8	Chincoteague National Wildlife Refuge	(459f-5) "...purposes of public outdoor recreation, including conservation of natural features...regulations applicable to national wildlife refuges,..."
26. 25 U.S.C. 564d 564w-1	Klamath Forest National Wildlife Refuge	(564w-1) "...designated as the Klamath Forest National Wildlife Refuge,..."
27. P.L.84-810 (70 Stat. 668)	Okefenokee National Wildlife Refuge	"To provide for the protection...Refuge,... against damage from fire and drought...."
28. 14 U.S.C. 2, 94	Coast Guard Research	"...shall engage in oceanographic research..."
29. 46 U.S.C. 441-445	Oceanographic Research Vessels	"...studies pertaining to the sea...and biological research;..."
30. 33 U.S.C. 1101-1108	Marine Resources and Engineering Development Act of 1966	(1104) "...Review...needs for natural resources from the marine environment to maintain our expanding national economy...."
31. 33 U.S.C. 1121-1124	National Sea Grant Colleges	(1121 and 1123) "...marine resources, including animal and vegetable life...provide...a program of...education, training, and research in the fields of marine science,...and related disciplines...'development of marine resources' means...including,...biological resources..."

Law	Title or Popular Name	Actions/Excerpts
32. P.L.89-302, 79 Stat. 1124	Marine Biological and Oceanographic Research Laboratory at LaJolla, California	"'...research on the living resources of the sea or their environment,...'"
33. 16 U.S.C. 1220-1220c	Reefs for Marine Life Conservation	"...Liberty ships for use as off-shore reefs. (a) Conservation of marine life...."
34. 16 U.S.C. 755-706ℓ	Preservation of Fishery Resources	(756 and 758) "...conduct...investigation,... and biological surveys...to...facilitate conservation of the fishery resourcesof the Columbia River...to perform all other activities necessary for the conservation of fish...to provide for...investigation,...of the fishing resources..."
35. 16 U.S.C. 777-777k	Fish Restoration and Management Projects	(777a) "...such research into programs of fish management...the acquisition of such facts as are necessary to...direct the regulation of fishing...including the extent of the fish population,..."
36. 16 U.S.C. 778-778h	Fish Research and Experimentation Projects	(778,778d) "...to develop suitable methods for harvesting the fish crop...to promote studies, research, and experiments...to develop... methods to reduce fish...in abundant supply... not now...sought after..."
37. 16 U.S.C. 779-779f	State Commercial Fisheries Research and Development Projects	(779a) "...to cooperate with the States...in... research and development of the commercial fisheries resources of the Nation..."
38. 16 U.S.C. 667a	Interstate Compacts	"...for the uniform,...regulation of fishing..."
39. P.L.77-539	Atlantic States Marine Fisheries Compact Act of May 4, 1942	"...to promote the better utilization of the fisheries,...ascertain...methods,...for... conservation...of the fisheries,..."
40. P.L.81-721	Act of August 19, 1950, Ch. 763, 64 Stat. 467	"...Atlantic States...Fisheries Compact, [amendation]...for...better utilization of its anadromous fisheries,..."
41. P.L.81-66 Act of May 19, 1949, Ch. 128, 63 Stat. 70	Gulf States Marine Fisheries Compact	"...to the better utilization of the fisheries... conservation and the prevention of the depletion..."

Law	Title or Popular Name	Actions/Excerpts
42. P.L.80-232, Act of July 21, 1947, Ch. 316, 61 Stat. 419	Pacific Marine Fisheries Compact	"...to promote the better utilization of fisheries,..."
43. P.L.87-766, 768 Stat. 763	Act of October 9, 1962	"[Pacific Marine Fisheries Compact - Amendation] ...programs for the conservation, protection... of fisheries..."
44. P.L.87-783, Act of Oct. 10, 1962, 76 Stat. 797	Potomac River Compact of 1958	"...a program of research relating to the conservation...of the fishery resources..."
45. 16 U.S.C. 1081-1086	Prohibition of Foreign Fishing Vessels in the Territorial Waters of the United States	(1083) "[Seizure of fish and foreign vessels fishing in U.S. waters]...Secretary of the Interior,...Treasury....Coast Guard...to carry out...enforcement...."
46. 16 U.S.C. 791a, 803, 811	Federal License of Water Resource Projects; Fishways	(803) "...developing a waterway...for... recreational purposes;..."
47. 16 U.S.C. 1001-1009	Fish and Wildlife Conservation at Small Watershed Projects	(1008) "...surveys and investigations...concerning the conservation and development of wildlife resources..."
48. 16 U.S.C. 460	Federal Water Project Recreation Act	(4601-12) "Recreation and fish and wildlife benefits of...water resource project, full consideration shall be given to the opportunities... which...affords for outdoor recreation and for fish and wildlife enhancement..."
49. 7 U.S.C. 1010-1013	Federal Assistance, Resource Conservation and Development Projects	(1010) "...a program of land conservation and... utilization,...to...assist in...preserving natural resources, protecting fish and wildlife,..."
50. 16 U.S.C. 460	Conservation Facilities at Water Resource Projects of the Corps of Engineers	(460d) "...lands...utilized [by lease] for the development and conservation of fish and wildlife...lessee may...cut timber...as may be necessary to further such beneficial uses...and... proceeds of any sales of timber...[to utilize] in the...conservation,...of such lands...."
51. 33 U.S.C. 540	Wildlife Conservation at Water Resource Projects of the Secretary of the Army	"...improvements of...waterways shall...include a due regard for wildlife conservation...."

Law	Title or Popular Name	Actions/Excerpts
52. 33 U.S.C. 608	Fishways at Rivers and Harbor Projects	"Whenever river...improvements shall be found to operate...as obstructions to the passage of fish,...cause to be constructed...sufficient fishways,..."
53. 16 U.S.C. 1301-1311	Water Bank Act	(1301) "...to conserve surface waters, to preserve and improve habitat for migratory waterfowl and other wildlife resources,..."
54. 33 U.S.C. 610	Control of Obnoxious Plants in Navigable Waters	"...for control [of obnoxious plants]...in the... interest of...fish and wildlife conservation,..."
55. P.L.85-245 (71 Stat. 563)	Statutes Relating to Specific Reservoirs under Jurisdiction of the Secretary of the Army: a. Reservoirs in Mississippi	"No reconveyance shall be made of mineral interests...if it...would adversely affect facilities...for the protection and management of migratory birds and fishing resources..."
56. P.L.84-459 (70 Stat. 67-68)	Demopolis Lock and Dam Project	"...excepting lands to be designated...for... protection and management of migratory birds and fishing resources..."
57. P.L.84-998 (70 Stat. 1064)	Jim Woodruff Reservoir, Florida and Georgia	"...lands...adjacent to the...Reservoir,... shall be retained...for fish and wildlife and recreational purposes...."
58. 43 U.S.C. 616	Baker Reclamation Project, Oregon	(616v) "...conservation...of fish and wildlife..."
59. 16 U.S.C. 695	Central Valley Project, California	(695d) "Development of water supplies for waterfowl management..."
60. 43 U.S.C. 620	Colorado River Storage Project Act	(620g) "...investigate...and maintain...public recreational facilities...and the wildlife on said lands,..."
61. 16 U.S.C. 835	Columbia Basin Project	(835i) "...fish-protection program..."
62. 43 U.S.C. 615	Crooked River Project, Oregon	(615i) "Preservation and propagation of fish and wildlife;..."
63. 43 U.S.C. 616	Fryingpan-Arkansas Project, Colorado	(616c) "Public recreational facilities; conservation;...and development of fish and wildlife;..."
64. 43 U.S.C. 615	Little Wood River Project, Idaho	(615m) "Preservation and propagation of fish and wildlife;...hunting and fishing;..."

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Law	Title or Popular Name	Actions/Excerpts
65. 43 U.S.C. 61¼	Washoe Project, Nevada-California	"...development of fish and wildlife resources,..."
66. 43 U.S.C. 616	Auburn-Folsom South Unit, Central Valley Project, California	(616ccc) "...maintenance of public outdoor recreation and fish and wildlife enhancement facilities,...preservation of recreation and fish and wildlife...potential,..."
67. 43 U.S.C. 616	Southern Nevada Project, Nevada	(616hhh) "Allocation to...fish, wildlife, and recreation..."
68. P.L.87-762 (/ Stat. 761)	Oroville-Tonasket Unit, Chief Joseph Dam, Washington	"...for conservation and development of fish and wildlife resources,..."
69. 43 U.S.C. 616	Tualatin Project, Oregon	(616ppp) "Conservation and development of fish and wildlife resources and enhancement of recreation...."
70. 43 U.S.C. 616	Auburn-Folsom Unit, Central Valley Project, California	(616fff-1) "...conserving and developing fish and wildlife resources,..."
71. 43 U.S.C. 616	Missouri River Basin Project, South Dakota	(616uuu) "Conservation and development of fish and wildlife resources..."
72. 43 U.S.C. 616	Mountain Park Project, Oklahoma	(616aaaa) "...conserving and develcping fish and wildlife resources,..."
73. 43 U.S.C. 1501, 1527, 1528	Colorado River Basin Project	(1527) "Fish and wildlife conservation and development...."
74. 43 U.S.C. 616	Palmetto Bend Project, Texas	(616jjjj) "Conservation; development of fish and wildlife resources; recreation. ."
75. 43 U.S.C. 616 [P.L.91-270, 84 Stat. 273]	Merlin Division, Rogue River Basin Project, Oregon	(616oooo) "Conservation of fish and wildlife and enhancement of recreation...."
76. 43 U.S.C. 616 [P.L. 91-307, 84 Stat. 409]	Touchet Division, Walla Walla Project, Oregon-Washington	(616tttt) "Maintenance of streamflow to ensure fish and wildlife conservation...."
77. P.L.89-108 (79 Stat. 433-435) Act of Aug. 5, 1965	Garrison Diversion Unit, Missouri River Basin Project, North Dakota-South Dakota	"...as will best promote the development...for recreation and fish and wildlife enhancement..."

Law	Title or Popular Name	Actions/Excerpts
78. P.L.90-136 (81 Stat. 444 et seq., Act of Nov. 17, 1965	Mid-State Division, Missouri River Basin Project, Nebraska	"...conserving and developing fish and wildlife..."
79. P.L.88-594 (78 Stat. 942) Act of Sept. 12, 19[illegible]	Pecos River Basin	"...for the conservation of fish and wildlife,..."
80. P.L.84-386 (69 Stat. 719) Act of Aug. 12, 1955	Trinity River Basin Division, Central Valley Project, California	"...the Secretary shall also allocate to the preservation and propagation of fish and wildlife,..."
81. 42 U.S.C. 4201, 4231	Intergovernmental Coordination	(4201) "...effective development and utilization of...natural resources;..." (4231) "...the concurrent achievement of the following specific objectives...Wise development and conservation of natural resources, including...wildlife,..."
82. 49 U.S.C. 1653	Preserve Wildlife Refuges and Maintenance of Natural Beauty on Lands Traversed by Highway Projects	"...national policy...to preserve...wildlife and waterfowl refuges,..."
83. 23 U.S.C. 138, 2[illegible]4-207, [illegible],319	Related Highway Legislation (Preservation of Parklands)	(138) "...to preserve...wildlife and waterfowl refuges,..."
84. 16 U.S.C. 460ℓ-4 to 460ℓ-11	Land and Water Conservation Fund Act	"For the acquisition of land, waters,... for the preservation of fish or wildlife that are threatened with extinction..."
85. 16 U.S.C. 1271-1287 [P.L.90-542]	Wild and Scenic Rivers Act	(1281) "Any component of the national wild and scenic rivers system...administered by... Interior...shall become a part of the national wildlife refuge...utilize...for the conservation and management of natural resources..."
86. 20 U.S.C. 1531-1536	Environmental Education Act	(1532) "...to support research,...demonstrations, and pilot projects designed to educate the public on the problems of environmental quality and ecological balance,..."

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Law	Title or Popular Name	Actions/Excerpts
87. 16 U.S.C. 582a, 582a-1 and 582a-6	Forestry Research Programs	(582a-6) "...investigation relating to:... management of forest and related rangeland for production of forage for...livestock and game and improvement of food and habitat for wildlife;..."
88. 16 U.S.C. 528-531	Multiple-Use Sustained Yield Act of 1960	(528) "...the national forests...shall be administered for...wildlife and fish purposes...."
89. 16 U.S.C. 1131-1136	Wilderness Act	(1131) "...the preservation of...wilderness... [and its community of life]"
		(1133) "...[part of] national wildlife refuge system...wilderness areas shall be devoted to... scientific...conservation,...use...."
90. 43 U.S.C. 315, 315a, 315h and 315n	Taylor Grazing Act	(315h) "...rules...for cooperation with... agencies engaged in conservation...of wildlife interested in the use of the grazing districts...."
91. 48 U.S.C. Chap. 2-Alaska, Sec. 6	Alaska Statehood Act Relating to Fish and Wildlife	"[Selection from public lands; fish and wildlife resources] ...property of the United States... is specifically used for the sole purpose of conservation and protection of the fisheries and wildlife of Alaska,... [etc.]"
92. 16 U.S.C. 1451-1464	Coastal Zone Management	(1451) "The coastal zone is rich in a variety of natural, commercial,...resources...and the fish...and wildlife therein, are ecologically fragile...important ecological...values...are being irretrievably damaged..."
		(1452) "The Congress...declares that it is the national policy (a) to preserve, protect,... enhance,...coastal zone."
		(1461) "...make available...estuarine sanctuaries for...creating natural field laboratories...and make studies of the natural... processes..."
93. 42 U.S.C. 4321-4347	National Environmental Policy Act	(4321) "...policy which will encourage productive...harmony between man and his environment;... to enrich the understanding of the ecological systems and natural resources...ensure that... programs, including those for development and conservation...take adequate account of environmental effects...Seek advancement of scientific knowledge of changes in the environment... Assure assessment of new and changing technologies for their potential effects on the environment....

Law	Title or Popular Name	Actions/Excerpts
		management of...fish and wildlife,...Foster investigations, studies, surveys, research, and analyses relating to (1) ecological systems...'
94. 33 U.S.C. 1251-1376	Pollution Control in Navigable Waters	(1252) "...due regard...to conserve such waters for the protection and propagation of fish and wildlife, aquatic life and wildlife,..."
		(1254) "...studies of the effects of pollution,... on fish and wildlife,..."
95. 33 U.S.C. 1401-1444	Ocean Dumping	(1442) "...continuing program of research with respect to the possible long-range effects of pollution, overfishing,...changes of ocean ecosystems...."
96. 16 U.S.C. 742d-1, 33 U.S.C. 1155	Pesticide Research	(742d-1) "...studies on effects of insecticides,... pesticides, upon the fish and wildlife resources..."

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Appendix D: List of Expressed Federal Needs

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Informal Questionnaire Sent to Federal and State Agencies and Non-governmental Organizations

Subject: Wildlife Monitoring Program Plan in response to National Needs

1. Did you find those National Needs represented by your Agency's relevant mission(s) adequately spelled out?   If not, please attach.

2. Did you find your Agency correctly listed as a "USER AGENCY" for the information or data to be generated by the relevant projects collected in Section 3?   If not listed, or incorrectly listed, please indicate the project code numbers below:

Add the ______________________Agency to project code numbers:______________

______________ ____

____

Delete from project code numbers:____

____

3. Are there any matters of detail to which you would like to add? If so, please append information. Please use identifying code numbers for projects.

4. Of all the projects collected in both Sections 3 and 4, to which ten would you assign the highest priority? Please use identifying project code numbers. If you wish to add projects, please append.

1____________ (most urgent)   6____________

2____________   7____________

3____________   8____________

4____________   9____________

5____________   10____________

Please complete and return to: Dr. John H. Busser
AIBS/BIAC
3900 Wisconsin Ave. NW
Washington, D.C., 20016

Department of Agriculture

Domestic stock, animals on rangeland

Disease transport

Wildlife as a host reservoir of disease vectors which may be transmitted to domestic livestock, range animals and poultry

Forest Service, Department of Agriculture

Mangement of wildlife habitat/effects of land use change

Forage needs for deer

Insect surveillance re forest and land management

Atomic Energy Commission

Effects on wildlife of power plant siting

NOAA, Marine Fisheries Resources (marine fish and mammals), Department of Commerce

Endangered species

Behavior/migration/productivity/census

Effects of pollution

Effects of ocean environment on recruitment and distribution of fish stocks

Distribution of schooling species/migration routes/resource management/ fishing capacity/forecast of location

Large marine animals/migration routes/resource management/ fishing capacity

National Marine Fisheries Service, Department of Commerce

Marine mammal abundance

Census/size/physiological data

Biomass, population size

Tuna, skipjack/migrations

Sockeye salmon population

Prediction of safe harvesting and breeding levels

Resource management

Pollution indices/sentinel species?

Council on Environmental Quality

Sentinel species for pollution - behavior/seasonal migration

Indices of wildlife quality

Census methods for seal, bowhead whale, dugong, manatee, sea otter, polar bear, walrus, canvasback duck, caribou, Puerto Rican parrot

Endangered species

Accurate estimates of number, distribution and habitat availability for development of adequate protective measures and recovery plans

Predator species

For investigation and monitoring the relationship between predator densities, natural prey densities and predation on domestic stock

Marine species

Full development of technological applications for wildlife in the marine environment

Technology for censusing and tracking small cetaceans and seabirds

Wildlife indices of environmental quality

Corps of Engineers, Department of Defense

Impact on wildlife habitat

From land dumping, reservoir construction, water impoundments, channel modification, wetlands - ecological data as well as migratory routes, breeding habitats

Effects on marine resources of deep water ports

Wildlife distribution and reaction patterns

U.S. Navy, Department of Defense

Noise interference in naval operations (animal sources)

Marine mammal migratory routes

Seasonal concentrations of populations

Physiology of deep-diving mammals as analogs for human work

Pelagic shark monitoring

Environmental Protection Agency

Relationship of environmental indices and sentinel species

Behavior and response

Communicable Disease Center (domestic and wild animals), Department of Health, Education and Welfare

Venezuela -- equine encephalomyelitis

Florida and California -- Newcastle disease

South Dakota -- duck virus enteritus (Dutch duck plague)

30,000 ducks in 15 areas lost without trace Jan./Feb. 1973

Southeast U.S. -- hog cholera

How many feral swine there are, where they are and their numerical distribution

Texas border -- cattle fever tick

Deer/cattle ratio, their distribution and migration patterns

Hoof and mouth disease

Rinderpest

African swine fever

Vesicular exanthama - swine

Department of the Interior

Endangered species

Census taking

Migrations and routes

Behavior

Resource significance

Bureau of Sport Fisheries and Wildlife, Department of the Interior

Conservation and management of wildlife

Wildlife migrating between the U.S. and other countries, especially the USSR

Monitoring of predator activity re domestic stock

Migration, behavior and population studies (with NOAA):

polar bear, sea otter, walrus, manatee, caribou, birds

Effects of pesticides on birds

Browse and domestic grazing: habitat quality study

National Science Foundation

International Decade of Oceanographic Exploration (IDOE)

Research Applied to National Needs (RANN)

Department of State

Wildlife resources which transcend national boundaries/management

U.S. Coast Guard, Department of Transportation

Offshore fishing regulation and enforcement

Surveillance and identification of commercial fish schools

Monitor schools of tuna in Eastern Tropical Tuna Convention area

Monitor sentinel species in pollution problems

Appendix E: List of Expressed Needs of States

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Wildlife Management Survey Questionnaire Sent to States

Please list the most important problems in your State having to do with monitoring, census-taking, and management of wildlife. For example: "The need to develop an effective method for taking a deer -- or turkey -- census."

1.
2.
3.
4.
5.
6.
7.

Please list: (1) those technologies which you think would be of value to wildlife management personnel in carrying out their responsibilities, and (2) specific items of equipment which need to be developed. For example: "Infrared sensors may be of value in detecting deer under tree cover; satellite or aerial photography should be of value in detecting and counting large animals in open terrain; and a need exists for improved, standardized wildlife monitoring equipment -- sensors, telemetry, etc."

1.
2.
3.
4.
5.

Please describe the benefits accruing to your State if one or more of the problems listed above were solved.

How much money does your State spend annually on wildlife management:

If a conference on "Technology Applied to Wildlife Management" were held this summer, which one person from your State would you recommend attending:

Statistical Information

1. Name____________________ 2. Date____________________

3. Position____________________ 4. Mailing Address____________________

I. <u>Important State Problems</u>

1. Detecting meaningful changes in habitats -- vegetation.

2. Determining what constitutes ideal habitat for a variety of species.

3. Determining proper use levels of specified plants by specified animals.

4. When two different species of animals (i.e., livestock and antelope) use the same plant or plants, a method is needed to determine which species used how much of what.

5. It is desirable to accurately count wildlife.

6. Land use data and update:

   Forest land -- by type
   Agricultural land -- by type
   Transportation
   Mining operations
   Urban areas
   Wetlands, lakes, ponds, rivers and streams
   Recreation land
   Dwelling counts, i.e., camps, houses around bodies of water, camp roads, etc.

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7. Censusing

   Number and distribution of animals
   Daily and seasonal movements of animals
   Number and distribution of sport hunters and fishermen and commercial fishermen
   Location of animal wintering areas, waterfowl concentrations, nests, i.e., eagle, osprey, etc.

8. Climatic information, i.e., snow depths and profiles in open and in various covers.

9. Determination of:

   a. Soils data -- broad classifications
      Soil type
   b. Vegetation
   c. Numbers and distribution of species
   d. Daily and seasonal movements
   e. Animal tracks
   f. Animal wintering areas
   g. Bird nests
   h. Bird concentrations
   i. Dwelling count for all lakes, ponds, etc.
   j. Heat sensing and monitoring, Maine Yankee-Mason steam plant

10. Method for censusing deer in hardwood and hemlock forest.

11. Aerial photography for censusing waterfowl on open water (wintering waterfowl).

12. Aerial photography for censusing breeding waterfowl in a variety of cover.

13. Something that could identify, by species, wildlife to woodcock size within 200 feet of either side of a selected route.

14. Method for monitoring hunting activity.

15. Method for monitoring wildlife in a selected area, one to two acres in size such as those areas we have altered as an improvement for game.

16. Accurate and practical method of censusing deer, both extensive and intensive.

17. Accurate measure of fawn mortality - telemetry program.

18. Censusing: lion, bear, coyote, doves, pigeons, turkeys, squirrels, sage grouse, sierra and ruffed grouse.

19. Sampling non-game wildlife populations.

20. Correct low mule deer fawn survival rates.

21. Determine means of reversing the downward trend in pheasant numbers.

22. Evaluate the merits of habitat improvement programs.

23. Sample blacktail deer populations in heavy cover.

24. Predicting deer hunting success in advance of season.

25. Countering the anti-hunting sentiment.

26. Documenting the role of predators, especially coyotes as they affect wildlife.

27. A statewide deer census that would provide accurate distribution of patterns for all seasons of the year as well as detailed age and sex composition of the herd.

28. An economical method for obtaining accurate quantitative as well as qualitative land use measurements for all seasons of the year and the relationship of all game populations to the various land use types.

29. A refined method of determining proper deer densities in relation to existing habitat types in various areas of the state.

30. An accurate, economical method of obtaining statewide information on distribution and densities of all carnivore species: fox, raccoon, skunk, etc.

31. A method of accurately pinpointing hazardous or potentially hazardous sources of water pollution.

32. Improved methods for censusing deer, moose, bear, timber wolf.

33. Determining area of shallow water available for breeding ducks in different years.

34. Determining date of fall overturn and mixing of lake waters for series of lakes to determine when best to collect mixed water samples.

35. Deer census.

36. Anadromous fish census.

37. Census of swan (whistling) population.

38. Tracking migration of swans.

39. Protecting aircraft from the potential hazard of swans.

40. Census of deer and elk by area and/or habitat type.

41. Develop a system to determine carrying capacity of our big game (deer and elk) ranges.

42. Census of turkey, pheasant, sage grouse, ptarmigan, sharp-tailed grouse and quail.

43. Develop techniques for measuring deer and elk winter loss.

44. Statewide habitat inventory by type and changes occurring within.

45. Rapid evaluation on a large scale of grazing impacts by wildlife and domestic animals.

46. Method of marking large numbers of fish without time-consuming, expensive hard labor.

47. A rapid census technique for most wildlife species, allowing extensive use annually.

48. Removal of limitations imposed on present telemetry methods by power supply.

49. Identification of sources of thermal and other pollution.

50. To monitor the existing range as to type of class in order to determine extent of critical winter food and cover.

51. To determine the plant species compositions on the above type classes by percentage of makeup of each.

52. Determine the accuracy of current game census techniques -- what percent of the animals in an area are actually observed?, etc.

53. Monitor radio-equipped animals more frequently at lower cost than current SEL and rotary wing aircraft cost for this service.

54. Develop ultra-light, functional radio transmitters to attach to game animals. Current battery weight for an elk or moose is approximately four to six pounds. This causes collar stress and material breaks and cracks allowing moisture to cause malfunctions. Battery life is maximum of twelve to eighteen months. This is not enough when monitoring long life, big animals.

55. Delineation and classification of all wetlands (Types I through VIII) in Minnesota -- regardless of size.

56. Detailed cover maps of forest, agricultural and non-agricultural lands, e.g., changes in cropping patterns, amount of fall plowing, existing forest openings and species composition of woodlands.

57. Detailed mapping of existing waterways -- rivers, streams and man-made drainage systems.

58. The identification of ground water discharges to lakes and streams.

59. Statewide stream temperature profiles throughout the year to aid in identifying waters with potential for trout management.

60. Vegetative mapping of lakes, with emphasis on emergent strands of value to fish and wildlife.

61. Annual acreage determinations of naturally occurring wild rice stands.

62. An inventory of man-made d rice paddies -- numbers, locations and sizes.

63. Identification of effluent discharges to Minnesota lakes and streams.

64. Annual identification of lakes with nuisance algal blooms and a ranking of algal problems by statewide index.

65. Identification of wildlife concentration (e.g., deer yards) and responses of populations to habitat manipulation.

66. Enumeration of potential barriers to fish movement (e.g., waterfalls with a vertical drop of six to fifteen feet).

67. Adequate surveys to measure and assess impact of habitat changes. Species such as the sharptail, prairie chicken, and whitetailed deer are examples of game animals having very specific habitat requirements. At present there is no methodology available to:

    a. identify these habitat sites quantitatively or qualitatively;

    b. identify critical sites in relation to proposed or projected land use changes.

    (High altitude monitoring devices have the capability to provide this information.)

68. Accurate census methods are always needed, particularly for big game species in problem areas. An absolute census, for example, of deer and antelope in the Sandy Hills (Nebraska) would enable the agency to increase management efficiency.

69. Surveys of unproductive fishing waters (i.e., basic temperature data through the season, water depth, quality, etc.) are needed before possible management of these presently unproductive waters could be initiated.

70. Census of waterfowl using the Platte Valley is needed. This is an important migration stopover.

71. Census of angler use -- fishing pressure on various lakes and streams.

72. A method to analyze the land use inventory specifically through the identification of signatures of cover types associated with a species or group of species. This would aid in habitat mapping and species density comparisons.

73. A means of efficiently censusing game animals, such as deer and antelope. The difficulty seems to be in area of canopy penetration in coniferous cover and also in differentiating game animals from domestics.

74. Water identification to depict ponds as small as one-half acre.

75. General survey and monitoring of water temperature, pollutants, chlorophyl content, plankton distribution, biological productivity and water depths.

76. Survey of road traffic density related to use of public recreation areas.

77. The single most important problem in managing Florida's wildlife is the maintenance of wildlife habitat. Wildlife environs are deteriorating, shrinking and otherwise being converted to other uses. Habitat destruction is sometimes obvious, and at other times it takes place in hidden and almost insidious ways. In the future our effectiveness in managing wildlife populations will depend on our ability to identify those areas of critical concern and those changes that are taking place in specific habitat types. To this end we are in need of:

    a. an effective method of inventorying habitat types;

    b. an efficient system of maintaining a habitat inventory; and

    c. an effective remote sensing capability that would detect and monitor the alteration of wildlife habitat.

    In addition, existing management techniques need to be augmented by (1) an effective method of censusing large mammals, (2) a censusing system that would provide a species identification capability and (3) a remote sensing technique for monitoring wintering waterfowl populations.

    There are many potential indirect aspects wherein this technology could provide valuable assistance and be a primary tool in carrying out many aspects of our work. It is quite interesting to think of the implications that this technology might afford in the area of detecting and monitoring pollution, the mapping of submerged and emergent aquatic vegetation (native and exotic), monitoring the effects of floods and droughts, the measurement of changes in watershed drainage patterns, the determination of or separation of wetlands from uplands, the management of coastal zones, the determination of minimum habitat requirements for rare and/or endangered species and the detection and monitoring of illegal dredge and fill projects. The eventual benefits could easily lie in the unknown capabilities that will probably appear as this technology matures.

78. More e[illegible]ective method to census deer, bear, wild turkey, pheasant, rabbits, ruffed grouse and other wildlife populations.

79. More effective method to determine daily activity and movements of the cited species.

80. Censusing deer and determination of post-natal fawn mortality.

81. Determining illegal kill of game, in and out of season, especially deer.

82. Vegetative inventories to determine priorities for habitat improvement treatment.

83. Wetlands inventories that would permit qualitative analysis of waterfowl habitat.

84. Monitoring of habitat destruction, e.g., stream channelization, land clearing, land drainage, urban sprawl and persistent pesticides.

85. The need to periodically inventory beaver dams and lodges and discriminate between active and inactive lodges.

86. Daily monitor the Chesapeake Bay area for oil spills.

87. Daily monitor turbidities in all waters of the state and discriminate between plankton and sediments.

88. A method for recording migration of birds (game and non-game) and measuring effects of electric transmission lines on migration and possible mortality.

89. A method of measuring public use on impoundments, streams and wildlife management areas without resident managers.

90. A rapid method (other than fire tower or airplane) for detecting forest fires.

91. Solving problems relating to successfully passing migrating adult and juvenile salmon at dams.

92. Estimating populations of salmon, shellfish and various marine fishes as they occur in rivers or coastal marine areas.

93. Monitor environmental impact of highway construction, stream channelization -- by recording habitat conditions before and after construction.

94. Deer, black bear, grizzly bear, moose, mountain sheep, turkeys and other upland game bird populations are impossible to census with present known methods.

95. Develop method to enumerate feral p.. and blacktail deer in dense rain forests.

96. Develop technique for tracing movement of Hawaiian geese on lava flows and in forests.

97. Develop census technique for feral goats which live on precipitous cliffs.

98. Capturing sufficient numbers of wild animals to facilitate valid studies is often difficult. Better techniques, drugs and mechanical devices are needed.

99. Long life telemetry transmitters are needed at reasonable prices; perhaps solar powered equipment is necessary. Also, directional locating antennas and receivers need higher resolution powers, as some transmitter signals peak over too wide a compass range for exact location.

100. Monitor migrations: dove, snipe, woodcock, rail, waterfowl -- particularly wood duck in timber, shrimp and schooling fish in coastal waters.

101. The need for more information on the effects of disease in upland game populations.

102. Need for monitoring dog depredations on deer.

103. Need for detecting big game poachers in specific areas.

104. Need to monitor the "fall shuffle" in sub-adult grouse.

105. Need to determine percentage of diseased animals (deer, foxes) in large areas during outbreaks of rabies, blue tongue or EHD.

106. Need to develop an effective method of mapping:

   a. vertical and horizontal thermal gradients in streams and impoundments;

   b. turbidity in streams and impoundments;

   c. both emergent and submerged aquatic vegetation;

   d. nutrient distribution, especially nitrates and phosphates;

   e. total dissolved solids;

   f. total dissolved oxygen; and

   g. total dissolved CO_2.

107. Need to monitor movements and numbers of hard-to-find animals such as black bear, bobcat and coyote.

108. Monitor movements and activities of free-roaming dogs, especially in relation to deer mortality.

109. Aerial census techniques for waterfowl using vertical photography and scanning counters.

110. Habitat monitoring using multi-spectral photographs from satellites.

111. Computer science application to data storage and retrieval, survey techniques, modeling, etc.

112. Medical physiology and pharmacology for handling wild animals.

113. Need effective techniques to census deer, elk, turkey, javelina, bighorn, lion, bear.

114. Determine reasons for low deer fawn survival.

115. Frequency of livestock kills by lion and bears and whether stock killers are certain individuals or any hungry lion or bear with the opportunity to make a kill.

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II. Important Technologies and Desired Equipment

1. Device or method for obtaining meaningful data concerning the habitat.

2. Automatic digitation of land use and pollution (including thermal) source data to facilitate computerized mapping for update and monitoring purposes.

3. Infra-red sensors.

4. Development of automatic equipment for determining and cataloging signatures of animals, pollution sources, algal blooms, etc.

5. Infra-red monitoring of entire river drainage for:

   a. pollution - sources and dispersion;

   b. surface water temperatures;

   c. flows and water levels.

6. Infra-red monitoring of River Estuary for:

   a. salinity;

   b. flushing rates;

   c. tidal currents.

7. Telemetry in all phases.

8. Ability to read sensitive photos.

9. Sensors that can pick out moving waterfowl in thick cover on marsh surfaces.

10. Computer science.

11. Telemetry.

12. Infra-red sensors.

13. Aerial photography.

14. Improved telemetry equipment and technique.

15. Remote sensing capability to census big game animals.

16. Improved trapping techniques for all wildlife.

17. Remote sensing to measure big game population trends in heavy cover.

18. Twenty-four hour surveillance of coyote activity, using a more suitable technique than telemetry.

19. Damage control devices to resolve conflicts between big game and agriculture.

20. Improved technology to monitor wildlife populations (game and non-game) economically, accurately and swiftly at all seasons of the year.

21. Infra-red sensing and photography for counting big game animals.

22. Temperature sensors (which can broadcast temperatures) to be attached to fish to determine their thermal tolerances and preferences.

23. Dissolved oxygen sensors (which can broadcast data) to determine tolerances and preferences.

24. Infra-red censors for deer.

25. High and low altitude photography.

26. Telemetry during migration.

27. Proximity sensors (counters) to record number of animals passing a given point.

28. Water warming techniques for fish hatcheries using nuclear or solar energy.

29. A heat or infra-red emitting device on animals for detection by aerial sensor.

30. Satellite telemetry to determine location of marked individuals with reasonable accuracy.

31. Further miniaturization of telemetry components or circuitry to decrease weight.

32. Need for various imagery photos of vegetation are essential to range management.

33. NASA could provide technical training to State personnel in photo interpretation.

34. Infra-red sensing coupled with high altitude photography to provide census and habitat data. Also, computer printout of diversity or nearest neighbor association is needed for a qualitative habitat approach.

35. Interpretation of imagery requires a certain degree of specialization. Wildlife people will need to be cross-trained before their experience and judgment can be fully utilized.

36. Research needs to be continued in developing interpretation equipment which can be programmed to identify and translate imagery.

37. A need for standardized telemetry equipment.

38. A refinement of infra-red sensing equipment is needed for wildlife censusing.

39. Use of satellite or high altitude photography needs to be investigated for its application in habitat studies.

40. Coupling of sophisticated, multipurpose monitoring equipment capable of recording changes in animal and fish life with that capable of recording changes in air and water quality might help clarify questions about pollutant impacts on species.

41. Developing equipment capable of producing large area sound or odor might be of value for "herding" endangered or rare species to protected areas.

42. More efficient telemetry equipment.

43. Improvements in infra-red imagery, multispectral imagery, radio tracking and telemetry.

44. Improved satellite photography, remote TV scanning and satellite monitoring of radio-telemetry gear attached to animals.

45. Remote sensors of bodily functions as indication of physiological response to environment.

46. Equipment for observing and/or recording activities of wildlife at night or other times when normal vision is obscured.

47. Monitoring equipment for limnological chemistry of streams and impoundments.

48. Equipment for marking and following fish.

49. Sophisticated scanning equipment which permits observing fishes under water would aid greatly in assessing fish populations, distribution and general behavior.

50. Chemicals or other means of <u>inexpensively</u> and <u>selectively</u> controlling competitive or predaceous fish populations and for controlling the growth of aquatic vegetation could greatly improve salmon production in streams and large impoundments.

51. High resolution aerial photography for plant type identification as related to habitat/population estimates.

52. A reliable self-triggering photo recorder for wildlife species.

53. Improvements needed in animal tracking telemetry.

54. Remote sensing devices for monitoring specific functions of animals. "In my case, I need a device to monitor the gobble of individual wild turkey toms in order to learn more of specific gobbling behavior of the adult and juvenile gobblers."

55. In managing our deer herd, effective infra-red sensors used to periodically locate and enumerate our herd would help evaluate land management practices and harvest requirements, as well as assisting hunters in locating their quarry.

56. Miniaturization of radio telemetry equipment.

57. Infra-red sensors to detect deer under tree cover.

58. Radio telemetry equipment offering more dependability and greater ranges.

59. Sensors for detecting entry into area by unauthorized personnel.

60. Economically feasible equipment to monitor movements of radio-equipped wildlife and improved power sources for the transmitters used -- smaller and with an operational life of at least a year.

III. Benefits to the States

1. Be in better shape to cope with the main problem of wildlife management -- land being used up for coal mining, roads, towns, clearcuts, etc.

2. Better understanding of the resources and therefore improved ability to use them.

3. Better handle on deer range carrying capacity which would lead to more meaningful antlerness quotas.

4. Improved management of wildlife populations.

5. Refinement of seasons and bag limits.

6. Better acceptance of wildlife management principles by public.

7. Would provide additional knowledge necessary to confidently manage wildlife populations for the most efficient utilization of the resource.

8. Allow better wildlife management on a prescribed area basis.

9. Better estimate of waterfowl production.

10. Have no real knowledge of size of deer herds at present. Improved technology would provide great benefit to harvest management.

11. Bird hazards to aircraft.

12. An appreciation of our wildlife resources.

13. Streamline operations and make them more efficient.

14. Better and more efficient management of existing resources.

15. Potential for increase in resources with resulting increase in opportunity for participants.

16. Will improve economy of state.

17. Make concrete recommendations to local managing agencies to stabilize game herd levels. This would make animal management more of a science instead of the present guesswork type operation involved in many instances.

18. The benefit of accomplishing any of our several proposals would be a savings of approximately five man-years in labor and expense. It would give almost "instantaneous" identification of problem areas, rather than devoting time (as is currently done) to identification and evaluation of problems --

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only to find out it's too late to do anything. In other words, it would take wildlife management out of the ranks of always fighting a "rear guard action."

19. At present, surveys, inventories and, in general, overall management are the result of on the ground observations. The time element and manpower required to collect and interpret data from 77,950 square miles reduces our ability to function as managers. The ability to observe and properly analyze regional and statewide areas as a whole and on a current seasonal basis will increase the validity of estimating reproductive success (based on nesting cover, for example) or over-wintering (based on snow cover or crop removal, for example). The applications of this, of course, extend into the fisheries portion of wildlife management.

20. If the cited problems were solved, we would be better able to protect, preserve and manage wildlife habitat and individual wildlife species. Resources could be allocated more efficiently and effectively.

21. One measure of the importance of deer in Michigan is license sales -- over half a million annually, bringing in revenue of around $3 1/2 million. Any refinement or improvement in administration or management of this resource is of great importance.

22. Wildlife resources could be managed more effectively and the effects of major land use practices on wildlife habitat could be more accurately assessed. This increased efficiency would be worth millions of dollars in the form of additional annual recreational opportunities to North Carolina hunters.

23. The benefits would be better management of an expendable resource.

24. Problems related to deer mortality, particularly fawn mortality and "dog-kills," would be useful in terms of habitat development and developing public sympathy for stricter dog curbs.

25. Dog depredations and deer poaching are serious problems which limit our deer herd. If solved, would increase deer populations with economic benefits accruing to state and local communities.

26. Accurate population estimates of deer and turkey would greatly assist in harvest manipulation, setting of seasons and bag limits.

27. Determining concentration of diseased wildlife would facilitate control and treatment.

28. The management of our wildlife resources could be more intelligently conducted and with increased accuracy, economy, and less manpower and man-days effort.

29. Benefits would include:

    a. greater accuracy in censuses, resulting in better game management programming;

    b. cost-savings on personnel time; and

    c. better assessment of environmental impact of proposed projects or activities.

30. Wildlife population surveys would permit improved harvest regulations consistent with carrying capacity of the habitat.

31. Benefits to the state (Oregon) could easily exceed $1 million annually.

32. The annual inventory of cover type statewide would identify, at an early date, trends in habitat loss or conversion to other cover types. This would permit a more rational evaluation of existing wildlife population trends and enable predicting more precisely the anticipated wildlife supply for future demands within the scope of our long range wildlife management plan.

33. Since Maryland hosts approximately 60% of the Atlantic flyway waterfowl population, early detection of major oil spills could have a significant bearing on any waterfowl rescue effort.

34. If we (Arizona) had techniques to permit determining population density of various species of big game, we could do a fantastically better job of management. We could then determine annually the desired kill, basing it on the reproductive capacity of the animal, the carrying capacity of the area, as well as the population level. Number of hunters could be determined for each species and each area. Public relations problems with both hunters and non-hunters would be immeasurably simplified as a result.

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Appendix F: Technical Information on Specific Requirements for Biological Measurements

Part I: Biological Data Needs

Part II: Technological Approaches

Part I: Biological Data Needs

Census (Table 3). The need is for data which will allow an estimate of total population to some required confidence level (typically ± 5% to ± 20% to an 80% confidence level).

The frequency of census data needed ranges from daily (i.e., during a salmon run) to once every thre years (for certain wildfowl).

For the animal types analysed, raw census data requirements vary from one or two animals per sq km to the "solid" appearance of some bird flocks or salmon runs when in a favorable habitat.

There may often be a two step process to censusing. Determination of whether or not a habitat is favorable is first based on kinds of vegetation, topography ther characteristics; if an area is favorable, then a ground or aerial survey is made. In some cases there is sufficient knowledge about animal habits to permit a census by habitat area alone, with spot checks on the ground only to verify the basic density multiplier.

Location (Table 4). The need is for obtaining data which locates identifiable animals or groups of animals (herds, flocks, pods). In order of increasing difficulty this involves:

- Large animals in open habitat
- Birds in flight over contrasting background
- Birds in flight over concealing background
- Small animals in open habitat
- Large animals under concealing canopy
- Small animals under concealing canopy
- Animals in de... burrows or under water, ice or snow.

There is need for locatio... night and all times of the year. Ground truth verification must be provided to assess the completeness and accuracy of results obtained by surveillance systems.

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The normal animal movement expected varies from containment within a home range circle with a 10 km diameter to a migration of 9000 km. Animals move with speeds up to 50 km/hr.

The accuracy required for locating animals varies from $\pm$ 10 - 100 m for animals in a group not in motion to $\pm$ 0.5 - 10 km during migration, hunting or foraging.

The frequency needed for this measurement varies from continuous tracking to twice yearly.

Behavior (Table 5). Variables of interest include the time spent in hunting, feeding, breeding, flying, resting, diving, on a nest, in a burrow, in motion activity, nursing and hibernating. For most of these activities sensors in a field-ready package to be applied to various animals do not exist in most cases.

The resolution required varies from $\pm$ 5 - 25%.

The frequency of coverage varies a great deal according to the animal, i.e., continuous, twice per day to differentiate day/night activity, 12 times per day and per dive.

Physiology (Table 6). Frequency of coverage varies from continuous to daily, or · per hour being the most common.

Habitat (Table 7). Frequency of coverage varies from continuous to once per year, twice per day being the most common.

Detection and Identification (Table 8). Resolution required for detection varies from .03 to 5 m, for identification from .2 to 1 m.

Table 3. Census

Animal	Datum	Range (individuals)	Resolution (%)	Frequency of Coverage
Wildfowl	Total	10^3 - 10^8	± 20	12 per year
Predatory carnivores	Total	- -	± 5 - 10	1 - 2 per year
Porpoises and young whales	(School, pod)	10 - 10^4	± 10	1 per year
Polar and other bears	- -	1 - 20,000	"	2 - 4 per year
Rodents	(Colony count)	0 - 15 per 100 m^2	- -	2 per year
Raptors	- -	1 - 900	± 5	2 - 4 per year
Cattle	- -	10 - 10^3	"	12 per year
Bill fish	- -	100 - 200	± 20	6 per year
Deer	- -	1 - 9000	± 10	4 per year (seasonal)
Sheep	- -	"	"	12 per year
Turtles	- -	0 - 2 per km^2	- -	During nesting season only. Daily near coast and on beach.
Adult whales	(Individuals and pods)	1 - 10^3	± 20	1 per year
Other marine mammals	(In herd)	1 - 250	± 5	"
Salmon	(During run)	0 - 100% density per m^2 x depth	- -	Daily during run
Sessile shell-fish	N/A	- -	- -	- -
Passerine birds	(Individuals and flocks)	100 - 10^3 per 100 m^2	± 10	2 per year
Locusts	(Swarm)	To 10^6 per km^2 (1-5 km^2)	- -	Weekly when swarming

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Table 4. Location

Animal	Datum	Range	Resolution	Frequency of Coverage
Wildfowl	- -	Global	± 5 km	Daily to monthly
Predatory carnivores	- -	20 - 100 km dia circle	± 0.5 km	Daily to weekly
Porpoises and young whales	(School, pod)	100 m - 1 km^2 School travels 100 - 10^3 km	± 5 km	2 per mo
Polar and other bears	- -	500 km dia circle	± 1 - 5 km	Daily
Rodents	(Colony)	0 - 5 per km^2 (non-moving)	± 20%	2 per yr
Raptors	- -	10^3 km	± 0.5 km	Daily to weekly
Cattle	Sedentary	20 km dia circle	± 10 - 100 m	Daily
	Migratory	200 km dia circle	± 1 km	
Bill fish	- -	Global	± 10 km	6 per yr
Deer	- -	100 km dia circle	± 0.5 km	1 per hr - 2 per day
Sheep	- -	--	"	Daily
Turtles	- -	10 km dia circle	± 0.5 - 3 km	1 per hr - 1 per day
Adult whales	- -	Global	± 0.5 km	1 per day
Other marine mammals	Sedentary	100 km dia circle	± 1 km	"
	Migratory	500 - 2000 km	"	
Salmon	To locate buoy if it breaks loose	10 km dia circle	"	1 per hr - 1 per day
Sessile shellfish	N/A	- -	- -	- -
Passerine birds	Three dimensions X,Y,Z	Global, global, 10 km	± 1 km, 1 km, 0.1 km	Daily, daily, continuous
Locusts	- -	0 - 9000 km	± 1 - 5 km	Daily

Table 5. Behavior Variables

Animal	Datum	Range	Resolution	Frequency of Coverage
Wildfowl	N/A	--	--	--
Predatory carnivores	Time feeding	0 - 100% per hr	± 20%	Hourly to 2 per day
	Time hunting	"	"	"
	Time resting	"	"	"
	Time breeding	"	"	"
Porpoises and young whales	Time feeding	"	"	"
	Time diving	0.5 - 5 min per dive	"	Per dive or accumulate in % of hours per day
	Diving depth	0 - 300 m - 2000 m	± 5%	Per dive
	Respiratory rate as activity indicator	0.1 sec - 0.2 min	± 25%	1 per hr
	Diving rate	1 per min - 1 per hr	Diving or not	- -
	Swimming speed	0 - 20 km/hr	± 10%	2 per day
Polar and other bears	Feeding	0 - 100% per hr	± 20%	"
	Resting/hibernating	"	"	"
	Hunting	"	"	"
	Breeding	"	"	"
Rodents	Time in burrow	"	"	"
	Time on surface	"	"	"
Raptors	Time flying	"	"	"
	Time resting	"	"	"
	Time feeding	"	"	"
	Time in nest	"	"	"

Table 5. Continued

Animal	Datum	Range	Resolution	Frequency of Coverage
Cattle	Movement rate	0 - 40 km per day	± 10%	Daily
	Movement direction	360°	10°	"
	Time feeding	0 - 100% per hr	± 20%	2 per day
	Time resting	"	"	"
	Time breeding	"	"	"
	Reticulum activity	"	"	1 per hr
Bill fish	- -	- -	- -	- -
Deer	Time feeding	0 - 100% per hr	± 20%	1 per hr
	Time resting	"	"	"
	Time breeding	"	"	"
Sheep	Time feeding	"	"	Continuous
	Time resting	"	"	"
	Time breeding	"	"	"
	Time moving	"	"	"
Turtles	Movement rate	0 - 20 km/hr	"	Daily
	Movement direction	360°	10°	1 per hr - 1 per day
	Pitch angle	± 90°	"	Per dive
Adult whales	Diving frequency	1 per min - 1 per hr	Diving or not	Hourly
	Diving depth	0 - 8500 m	± 10%	"
	Time nursing	0 - 100% per hr	± 20%	2 per day

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Table 5. Concluded

Animal	Datum	Range	Resolution	Frequency of Coverage
Adult whales	Time feeding	0 - 100 % per hr	± 20%	2 per day
	Tailbeat	5 beats per sec - 1 beat per 2 sec	"	2 per hr
Other marine mammals	Swimming speed	0 - 20 km/hr	± 5%	1 per hr
	Dive rate	0 - 1 per min	Per dive	Per dive
	Dive depth	0 - 1500 m	± 5%	"
	Time on beach	0 - 100% per hr	± 20%	12 per day
Salmon	School movement speed	0 - 50 km/hr	"	Per day
	School movement direction	360°	"	1 per hr - 1 per day
Sessile shellfish	- -	- -	- -	- -
Passerine birds	- -	- -	- -	- -
Locusts	Time of hatching	1 per 7 years	Nearest day	On hatch day
	Larval time	- -	"	1 per day

Table 6. Physiology

Animal	Datum	Range	Resolution	Frequency of Coverage
Wildfowl	- -	- -	- -	- -
Predatory carnivores	Metabolic rate	- -	- -	Hourly
	Estrus	0 - 100% per day	± 50% per day	Daily
Porpoises and young whales	EEG (as sleep indicator)	0 - 100% per hr	Sleeping or awake	1 per hr
	Heart rate	20 - 120 per min	± 10%	- -
	CO_2 produced per kg body weight per hr	Unknown	± 5%	1 per hr
	EMG (electro-myogram	"	"	"
Polar and other bears	Metabolic rate	- -	- -	Hourly
	Estrus	0 - 100% per day	± 50% per day	1 per day
Rodents	- -	- -	- -	- -
Raptors	- -	- -	- -	- -
Cattle	Oxygen consumption	Per 6 hours	- -	4 per day
	Body temperature	30 - 40° C	± 2° C	"
Bill fish	Heart rate	10 - 50 per min	± 2 per min	1 per 3 days
	Body temperature	10 - 30° C	± 1° C	"
Deer	Metabolic rate	- -	- -	1 per hr
	Estrus	0 - 100% per day	± 50% per day	Daily
	Ingesting or voiding water	"	- -	1 per hr

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Table 6. Concluded

Animal	Datum	Range (individuals)	Resolution (%)	Frequency of Covera-
Sheep	Metabolic rate	- -	- -	Continuous
	Body temperature	- -	± 1° C	"
	Food consumed	% of body weight	- -	"
	Water consumed	"	- -	"
	Estrus	0 - 100% per day	± 50% per day	Daily
Turtles	Heart rate	0 - 75 per min	- -	1 per hr - 1 per day
	Body temperature	20 - 30° C	± 0.5° C	"
Adult whales	Respiratory rate	2 per min - 1 per hr	± 5%	1 per hr
	Heart rate	2 - 100 per min	"	"
	Body surface temperature	-4 - 30° C	± 0.5° C	"
	Body deep temperature	30 - 38° C	"	"
Other marine mammals	Body deep temperature	32 - 40° C	"	"
	Body surface temperature	-4 - 38° C	"	"
	Metabolic rate in CO_2/kg/hr	Unknown	± 5%	"
Salmon	- -	- -	- -	- -
Sessile shellfish	- -	- -	- -	- -
Passerine birds	- -	- -	- -	- -
Locusts	Reproducing	0 - 100% per day	± 50% per day	1 per day

Table 7. Habitat

Animal	Datum	Range	Resolution	Frequency of Coverage
Wildfowl	Vegetation type	10 types	Type per ha	2 per yr - 1 per 3 yrs
	Water area	- -	100 m^2	1 per week
	Water depth	0 - 5 m	0.2 m	"
	Ice/snow	Presence or absence per/ha	$\pm$ 20%	"
	Wind speed	0 - 15 m per s	$\pm$ 5%	1 per day
	Wind direction	360°	"	"
Predatory carnivores	Air temperature	- 20 - 60° C	$\pm$ 5° C	1 per hr
	Relative humidity	10 - 100%	$\pm$ 5%	2 per day
	Wind speed	0 - 100 km/hr	$\pm$ 10 km/hr	"
	Vegetation stage	- -	- -	1 per wk
	Light incident on the animal	Light/dark in 0 - 100% per hr	$\pm$ 50% per hr	"
Porpoises and young whales	Thermocline depth	3 - 300 m	$\pm$ 10%	2 per day
	Water surface temperature	-4 - 30° C	$\pm$ 0.5° C	"
	Below thermocline temperature	"	"	"
	Scattering layer	Presence or absence	--	"
Polar and other bears	Air temperature	-20 - 30° C	$\pm$ 5° C	1 per hr
	Relative humidity	10 - 100%	$\pm$ 10%	2 per day
	Wind speed	0 ->160 km/hr	$\pm$ 8 km/hr	"

Table 7. Continued

Animal	Datum	Range	Resolution	Frequency of Coverage
Rodents	Burrow temperature	5 - 20° C	± 1° C	2 per day
	Burrow relative humidity	40 - 80%	± 5%	"
	Vegetation type	- -	- -	- -
	Soil moisture	0 - 100%	± 10%	2 per day
	Wind speed	0 - 50 km/hr	± 5 km/hr	12 per day
	Wind direction	360°	± 45°	"
	Air temperature	-10 - 50° C	± 5° C	2 per day
Raptors	Air temperature	-20 - 60° C	"	1 per day
	Wind speed	0 - 150 km/hr	± 10%	"
	Wind direction	360°	"	"
	Relative humidity	10 - 100%	"	"
Cattle	Forage productivity	0 - 45° C	± 1° C	"
	Air temperature	-35 - 45° C	± 2° C	1 per hr
	Relative humidity	10 - 100%	± 5%	"
	Soil moisture	0 - 100%	± 10%	1 per day
	Wind speed	0 - 100 km/hr	"	1 per hr
	Wind direction	360°	"	"
Bill fish	Water temperature	10 - 30° C	± 1° C	1 per 3 days
	Water salinity	25 - 40 parts per thou	± 2 parts per thou	"
	Water optical density	- -	- -	"
	Current speed		- -	"
	Current direction	360°	± 10%	"

Table 7. Continued

Animal	Datum	Range	Resolution	Frequency of Coverage
Deer	Vegetation stage	--	- -	1 per day
	Air temperature	-20 - 50° C	± 5° C	1 per hr - 2 per day
	Relative humidity	10 - 100%	± 5 - 10%	2 per day
	Wind speed	0 - 80 km/hr	± 10%	"
	Is animal in shade	Light/dark	- -	1 per hr
Sheep	Vegetation stage	kg/ha	- -	1 per mo
	Vegetation type	10 types	Type/ha	1 per yr
	Air temperature	- -	± 1° C	Continuous
	Elongation	- -	Yearly total ± 2 cm	"
Turtles	Water temperature	15 - 35° C	± 0.5° C	1 per day
	Water current	Still or flowing	- -	1 - 2 per day
	Water current speed	0 - 30 km/hr	± 10%	1 per hr - 1 per day
	Vegetation biomass (chlorophyll)	10 - 100 m	Presence or absence	"
	Surface light intensity	- -	- -	1 - 2 per day
	At depth light intensity	- -	- -	"
Adult whales	Water temperature	-4 - 30° C	± 5%	1 per hr
	Water salinity	15 - 40 parts per thou	"	2 per day
	Th[illegible] depth	0 - 600 m	± 50 m	"

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Table 7. Continued

Animal	Datum	Range	Resolution (%)	Frequency of Coverage
Other marine mammals	Water temperature	-4 - 30° C	± 0.5° C	1 per hr
	Air temperature	-60 - 38° C	"	"
	Wind speed	0 - 130 km/hr	± 5%	"
	Wind direction	360°	"	"
Salmon	Water surface temperature	0 - 30° C	± 0.5° C	1 per day
	Floe ice	Floe dia 10 - 100 m	± 50 m	"
	Light intensity at depth	10 - 100 m	3 - 10 steps	"
	Water temperature at depth	0 - 30° C	± 0.5° C	"
	Water current	Still or flowing	- -	1 per day
	Water current speed	0 - 30 km/hr	± 5 km/hr	"
	Water current direction	360°	± 45°	"
	Magnetic field	0.7 G	- -	"
Sessile shellfish	Water temperature at depth	10 - 30° C	± 1° C	1 per hr
	Water salinity	- -	- -	"
	Water color	- -	- -	"
	Zooplankton count	0 - 10^4 per m^3	± 100	"
Passerine birds	Vegetation type	10 types/ha	- -	1 per yr
Locusts	Air temperature	-20 - 60° C	± 5° C	2 per day

Table 7. Concluded

Animal	Datum	Range	Resolution	Frequency of Coverage
Locusts	Relative humidity	[illegible]0 - 100%	± 5%	2 per day
	Wind speed	0 - 160 km/hr	± 10 km/hr	"
	Wind direction	360°	± 20°	"
	Vegetation stage	- -	- -	1 per wk

Table 8. Spatial Resolution Required for Detection And Identification

Animals	Detection	Identification
Carnivores	1.0 m	0.2 m
Polar bears *	0.3 m	0.3 m
Porpoises	1.0 m	0.2 m
Whales (small)	2.0 m	0.5 m
Whales (large)	5.0 m	1.0 m
Rodents	0.03 m	0.02 m
Cattle	1.0 m	0.2 m
Shellfish/bill fish	N/A	N/A
Deer	1.0 m	0.2 m
Sheep	0.5 m	0.1 m
Turtles	0.5 m	0.1 m
Pinnipeds	0.5 m	0.1 m
Salmon **	5.0 m	0.02 m
Passerines	0.02 m	0.02 m
Locusts ***	0.01 m	0.01 m

* Detection affected by target/background contrast

** Detection of the school

*** Detection of the individual. If swarming, 10.0 m sufficient.

C-3

Part II: Technological Approaches

Interrogation, Recording and Location System (IRLS)

Starting in 1966, the IRLS has been employed on the Nimbus 3 and 4 satellites for a variety of mobile platform position location and data collection experiments. It was used to track an elk in Wyoming over a 96 km range during a period of a few weeks in 1969.

The IRLS technique requires a transponder (ordered system) to be carried by the animal. Upon recognizing its specific address, the animal's transmitter is activated and a ranging signal sent to the satellite. The satellite receiver detects the signal's modulation and measures the time of arrival by comparing the signal with an on-board time standard. This time is a measurement of the range between the animal and the satellite. At a predetermined time shortly thereafter the measurement is repeated. The times of the first and second measurements are stored in the satellite and transmitted to a ground station on command.

Precise satellite orbit and the two range measurements provide sufficient data for computing the animal's position. Sensor data are modulated onto the animal-to-satellite transmissions.

The advantage of this technique is that it has been shown to be effective with medium to large animals and to provide location accuracies of three to five km. The platform weight of 10 kg can be reduced by employing microminiaturization components and solar cells for power. Use of known calibrating stations in the general region of the experiment could improve the position accuracy to better than three km.

Random Access Measurement System (RAMS)

This technique, planned for testing on Nimbus F in 1974, requires a stable frequency transmission generated from an oscillator carried by an animal. A low orbiting satellite measures the frequency of the received signal, which consists of the frequency of the transmitted signal plus or minus a doppler frequency shift. The doppler shift is dependent on the transmitter frequency, satellite velocity, satellite position and animal position relative to the satellite track. If the first three quantities are known, a locus of possible locations of the animal can be calculated. A second doppler measurement, combined with the first, gives the animal's location. Knowledge of the animal's previous location can be employed to resolve any position ambiguity.

The principal advantage of this technique is its narrow band width and low transmitting power requirements. The animal transmitter may be simple, permitting ease of implementation. No receiver is required. A disadvantage of the technique is the need for relatively high platform frequency stability (better than 1 part in 10^9 short term). Mutual interferences limit the number of platforms to 200 simultaneously in the view of the satellite. Sensor data are modulated onto the transmitted signal for determining biological and physiological parameters of the animal.

Omega Position Location Experiment (OPLE)

OPLE has been employed in conjunction with a single geostationary communications satellite (ATS-3) to provide almost continuous, near real-time position fix data and sensor information for a number of mobile vehicles (ship, buoy, aircraft, balloon and auto). It uses the transmissions from the U.S. Navy's Omega navigation system, a long range (10 - 13,000 km) transmission system operating in the 10.2 - 13.3 KHz frequency region.

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Reception from two pairs of Omega stations provides sufficient information to perform phase differencing measurements and give a position fix. In the OPLE technique the three Omega signals received at platform electronics are converted upward in frequency and transmitted to the geosynchronous communications satellite for relay to a ground station. Position accuracy is nominally ± 3 km.

Multiple Satellite Ranging

This real-time, nearly continuous technique for position/location and transmission of sensor data employs multiple, geosynchronous satellites whose field of view encompasses the tracking region of interest. A transponder is employed on the animal, and, on command from the ground, range signals are sent to both satellites. The satellites relay the two range signals and sensor data to an earth data collection station for position/location computation and sensor data processing.

This technique will normally require high power levels, five watts or greater, to reach the 36,000 km altitude of geosynchronous spacecraft. It will also require approximately six satellites, at a substantial cost, to provide near global coverage, which will not be required by other disciplines. In addition, these types of satellites do not view the polar regions; experiments involving polar bears, walrus and other polar animals will require other systems.

Spaceborne Interferometer

Numerous studies have been performed employing a satellite-based, long baseline (hundreds of meters), angle-measuring interferometer located on a geosynchronous satellite (three will provide near global coverage, excluding the polar region) to provide a real-time position fix. Sensor data can be modulated on the signals transmitted to the satellite or could follow immediately after for relay to a ground computation station. The interferometer consists of two mutually perpendicular, crossed elements of about 100 wavelengths. An angle measurement is obtained between the moving animal and one of the baselines of the interferometer upon reception of a radio frequency signal from the animal's transmitter. A second angle is determined using the second interferometer baseline. These two angles plus a range measurement between the satellite and the animal provide sufficient information for a position/location fix. (See Interferometer Figure 31 on the following page).

Implementation of long baseline, spaceborne interferometers has not been carried out and appears to require technological advances. The ATS-F will have a short baseline interferometer operating at six GHz that will provide experimental information on accuracy potential. The longer interferometers will require stiff booms and accurate information on satellite nutation to achieve position/location accuracies of better than two to five km.

Ground Based Position/Location Systems

Radar Techniques

Radar techniques can be divided into those related to surveillance radars and those related to tracking radars. Several S-band surveillance radars are owned by NASA. One, the AN/ASR-7 at Wallops Station, has been used briefly as part of a study to determine its sensitivity for bird detection when used in different modes.

Interferometer technique for measuring angles

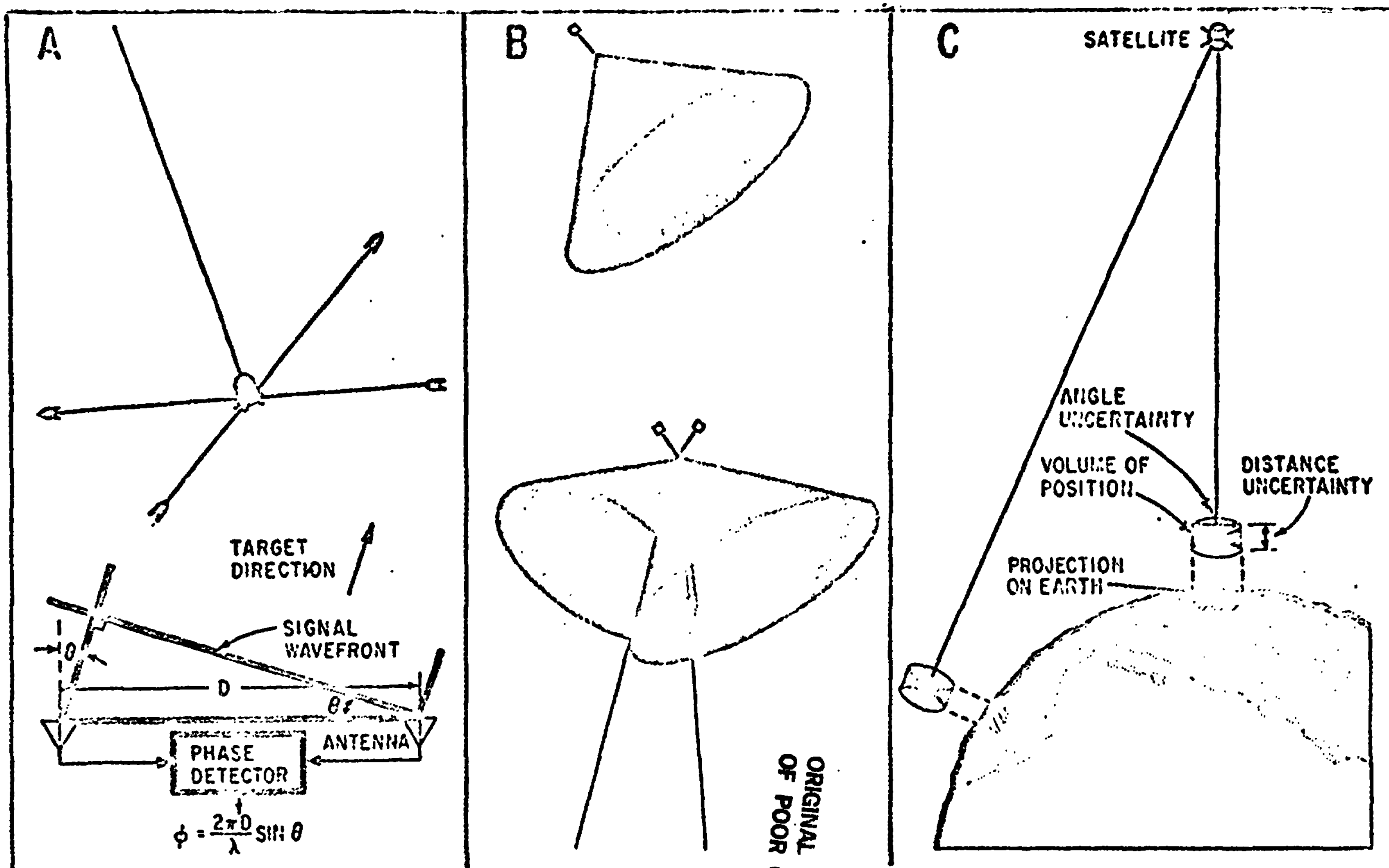

Figure 31

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One potentially important use of surveillance radars for wildlife monitoring is animal tagging with radar transponders. In existence today is a simple 50 g transponder which can be triggered by a surveillance radar to transmit information at a second frequency. When the radar is appropriately modified to receive the transmitted signal, the location of the "tagged" target can be displayed on the radar P.P.I. scope or automatically recorded. The detection range of the transponder depends on many factors, but under appropriate geometry a range of 100 km is possible.

. This technique is not limited to flying targets but can be used for monitoring animals on the ground, in which case, however, the range would be much reduced.

To date the primary capability of NASA for animal studies by radar lies with tracking radars. In general tracking radar offers the capability of studying the flight characteristics of airborne targets large enough to be detected. These include insects, bats and birds. The basic information to be expected depends on individual radar characteristics, but suitable radar choice will provide position as a function of time for single targets, the number density of "targets" in a suitable region around the radar, and the radar cross section of the "target" as a function of time. Interpretation of these kinds of radar data in terms of biological information is still in the research stage. However, it now seems possible that birds may be classified according to flight characteristics such as wingbeat rate, continuity of wingbeat, symmetry of wingbeat, altitude and speed of flight. Some indication of whether or not the bird is in long distance migration is also possible.

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Identification as to species is less certain. Work has been done on this using signature analysis of AGC records, but the scope of the work has been limited. Three to four years of effort are required with signature analysis before definitive answers are possible for a meaningful number of species.

In any application of radar to monitoring the densities of targets it must be recognized that a radar target can be a multiple biological target composed of all objects within the pulse volume of the radar. Pulse volume depends on many factors, some of which cannot be quantitatively determined. However, with the best radar systems available, minimum values would typically be 50 m^3 at 10 km and 6500 m^3 at 50 km.

It should be emphasized that tracking radars as they exist today were designed for targets with relatively high angular rates. For the application for which they are designed, tracking mount jerk and jitter do not seriously affect tracking accuracy. However, before extensive precise tracking experiments at low angular rates are performed, a systems analysis of tracking accuracy is needed. It may be necessary to redesign or modify existing mounts to meet the needs of biologists.

Other system modifications that may be necessary, but are usually available, are linearization of AGC output and provision for AGC frequency response above about 100 Hz. Careful consideration must also be given to data recording techniques since those in standard use at most radar facilities are not optimum for biological programs.

The primary NASA tracking radars -- established for satellite tracking -- are the C-band systems located on Figure 32. The most powerful of these

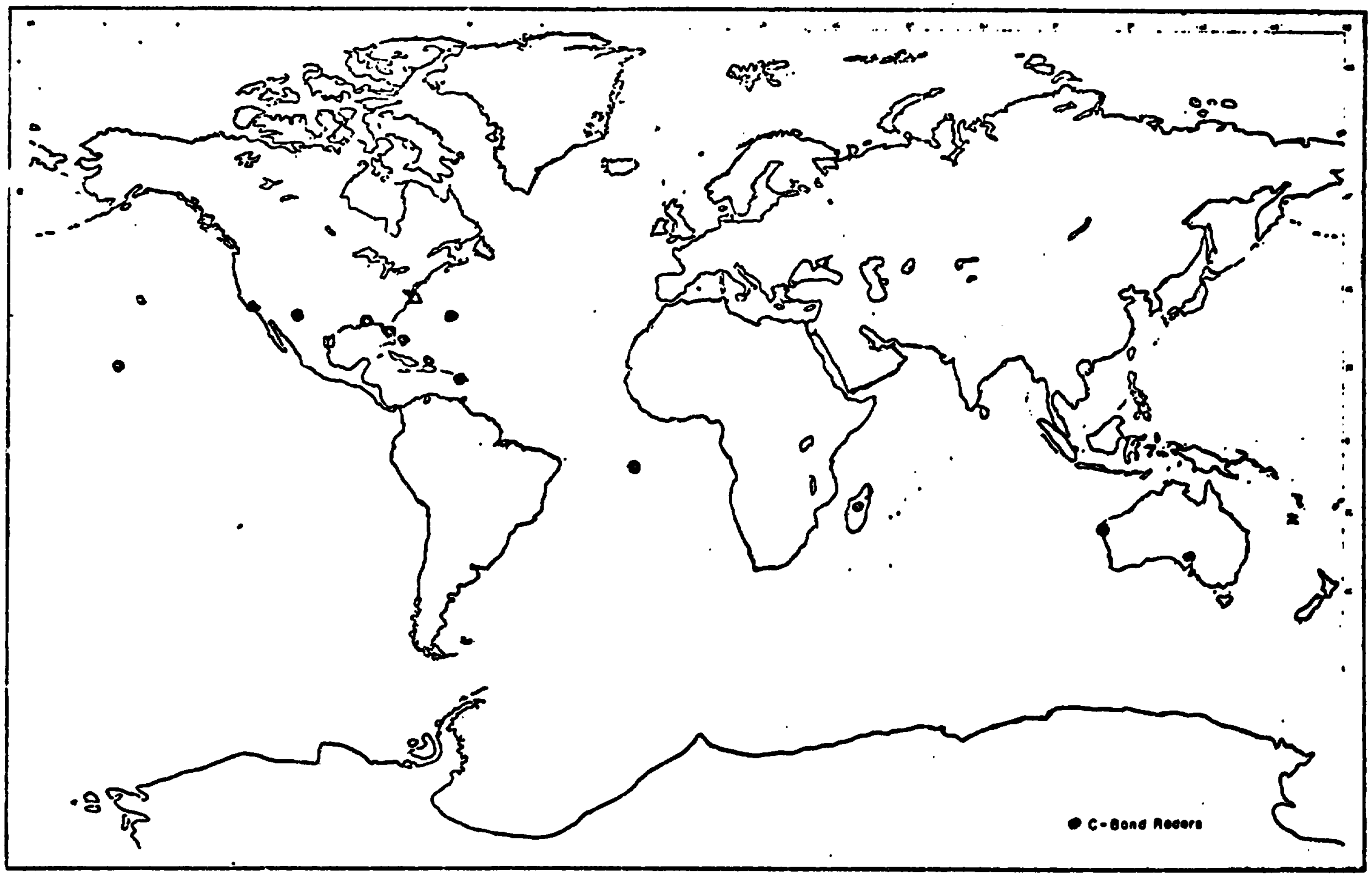

Figure 32. NASA SATELLITE TRACKING SITES

radars, the AN/FPQ-6, has tracked birds at a distance of more than 70 km.

NASA has allowed biologists to obtain data from tracking radars located at Wallops Station and Bermuda. At the same time grant funds have been provided to obtain cooperative data from surveillance radars located on Cape Cod, Antigua and Trinidad.

Also in existence are S-band and Ka-band tracking radars, located primarily at Wallops Station. The S-band radars are the AN/MPS-19 systems or modifications of them. They exist at fixed locations such as Wallops Station and in mobile vans. The Ka-band system exists at Wallops Station but is presently limited in usefulness because of tracking mount restrictions and lack of necessary circuitry for obtaining AGC. These problems, though, can be overcome by direct modification.

One other system owned by NASA but presently under operation by the Johns Hopkins Applied Physics Laboratory is the Radar Atmospheric Research Facility (RARF) located at Wallops Station. RARF now includes the Spander (S-band) tracking radar which, before 1972, was available from NASA for bird tracking studies. Included in RARF are UHF, X-band and S-band radars as a unified facility capable of giving multiple frequency information on a single target. The radar cross section of birds is frequency dependent, but the optimum frequency for identification of certain size ranges of birds needs more research.

Another system, totally unexplored for wildlife monitoring capabilities, is the high frequency over-the-horizon radar. This system could be used in conjunction with a radar transponder in the same manner as the previous sytems.

Other Ground Based Position Systems

Continuous wave (or sequential) transponding system using phase delay of subcarrier

General description. This type of system consists of two major components, a master station and a remote station. The master station sends out a radio frequency carrier modulated with a subcarrier. The remote station receives the modulated carrier and demodulates the subcarrier. In the continuous wave version the demodulated subcarrier in turn modulates another (different) radio frequency carrier which is sent back to the master station. There it is received, demodulated and compared to the original subcarrier. The phase delay measured is directly proportional to range.

A variation of this system operates in a sequential mode. Upon receipt of the modulated signal from the master station the remote station phaselocks an internal clock to the incoming subcarrier and goes into a hold mode. Upon cessation of the signal from the master station the remote station transmitter is turned on and modulated with the signal in the phaselock loop. Back at the master station this signal is received and compared as before.

This method allows transmission and reception on the same antenna at the same frequency, greatly reducing size and weight requirements. In both types radio direction finding techniques are used to obtain a bearing. Range and bearing fix the relative position of the master and remote stations.

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Existing systems. Systems utilizing the first technique are commercially available in designs primarily intended for such applications as position location for geophysical survey work. Typically they employ microwave and laser carrier frequencies and multiple subcarriers to resolve lane ambiguity.

A system utilizing the second technique has been built to monitor the position of porpoises undergoing training. It operates at a carrier frequency of 31 MHz and a subcarrier of 10 kHz (13 km lane).

The geophysic equipment would not be readily adaptable to animal work without extensive development. Their microwave frequency carriers do not perform well on low silhouette targets, and their size, weight and power consumption would have to be reduced by several orders of magnitude. The sequential system (#2) is presently configured in three cylinders 1 1/8" in diameter by 14" long. With its pressure housing and battery pack it weighs approximately three pounds. Without the pressure housing the weight is on the order of one pound. Range is zero to 9,000 m with a 9 m resolution and typically 27 m accuracy.

Proposed systems operating at lower carrier and subcarrier frequencies and capable of ranges from 160 to 320 km are feasible. Antenna size becomes a problem, however.

Development Necessary. An operational system compatible with a large marine or terrestrial animal exists. Adaptation for other applications where present size and weight are acceptable is an engineering task. Significant reduction in size and weight or extension of performance require engineering development work.

Standard Radio Tracking (radio beacon and direction finder)

General description. The system consists of small radio beacon at the subject and single or multiple radio direction finders. Frequency and power selection are based on subject size, habitat and range. Position information is obtained by tracking or multiple bearings on known baselines (triangulation). The radio frequency is also used to relay sensor data.

Existing systems. A wide variety of radio beacons and direction finders have been built and used. Many are commercially available. Beacons range in size from about one g, compatible with use on animals like mice, to very large packages on the order of 10 kg, used on elephants. Frequencies used cover low broadcast bands (.5 MHz) to 400 MHz. The kind of receiving equipment includes simple unipurpose receivers with some form of directional antenna such as a loop or yagi to automatic direction finders using eight arrays. Some systems include automatic, instantaneous display of bearings with facility for automatic identification and recording of events and bearings.

The technology of radio tagging is in one sense highly developed and in another just beginning. Small systems are generally restricted to monitoring a small number of animals, and their operation is carried out by a very small group of people. Technology exists to expand these standard systems into networks, but adequate individual funds for individual un-coordinated programs can rarely be mustered for investment in equipment and operational manpower. These smaller tracking programs serve to carry out the crucial step of identifying technological and operational problem areas associated with capture, handling and equipment/animal outerface which must accompany any tracking program using active or passive devices on the animal, no matter what the scale of the program.

Additional Development Areas. Equipment now being used is being invented and re-invented by each user. Successful programs usually can be identified by a good communications link between a biological scientist and a technologist or an exceptional biologist who has mastered the necessary equipment technology. Development in the area of general application modules or techniques is indicated. Their objective would be a family of devices or equipment backed up by technical support to interface the equipment with the program.

Passive Tagging

Several techniques have been utilized extensively to date. Passive tags have been designed either to identify the animal after recapture or death or to increase its visual contrast to allow visual identification.

Recent programs have been aimed at development of passive tags which, when illuminated with an electromagnetic source, re-radiate a coded signal for identification and counting. These systems use codes which allow very large numbers of individuals to be identified. Their present envisioned usage is primarily ground based, as in the identification of trucks and cattle (two known programs). It is conceivable that they might become part of a future system in which a satellite was employed as an interrogator and response relay.

Ancillary Data Systems

Orbiting satellite systems (other than geostationary) can be increased considerably in effectiveness through the use of ancillary systems. A single polar orbiting satellite operating only on the bright side of the earth will pass a given point at the lower latitudes only once per day. Yet some wildlife studies will require more frequent data coverage from sets of subjects. It seems reasonable to obtain such additional coverage through the use of receiver nteworks which are ground- (or sea-) based. Indeed such systems--using NASA technology--could go far to ameliorate severe communications problems known to exist with both pelagic marine animals and certain terrestial creatures.

Sensors (At Subject)

Among sensor technology immediately available are some devices fairly completely developed for application under field conditions or presently useful only under carefully controlled laboratory conditions, while others are poorly developed or unavailable.

Sensors generally are either of the implantable type or those which are surface-mounted. Past NASA developments as well as dynamic efforts in the medical field have produced a number of devices and sensor systems potentially appropriate for application to the wildlife program.

Since the wildlife effort here must relate to both the physiological and biochemical status of the subjects as well as environmental data local to the subject, both general classes of sensors are described in the text on Page 34. Where limitations in application are known, they are stated. Where known, clearly defined gaps exist in sensor technology, they are indicated.

Applicable Now	Existing but Limited in Application	Developmental
Physiological	**Physiological**	**Physiological**
Temperature	EEG	PH
Heart rate	EKG	Gas tensions
Blood pressure	Blood flow	Enzymes
		Pollutant absorption
		Voiding
		Pregnancy status
Behavioral	**Behavioral**	**Behavioral**
Simple physical activity	Heart load	Complete activity
Orientation	Selective activity	Food/water intake
	Phonation	
	Feeding events	

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Appendix G: Principles of Laboratory Animal Care Developed by the Ames Research Center

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1. All animals used for experimental purposes must be lawfully acquired, and their retention shall be in strict compliance with federal, state and local laws and regulations.

2. Research projects involving animals must be performed by, or under the immediate supervision of, a qualified biological scientist, with a Doctor of Veterinary Medicine in attendance.

3. The housing, care and feeding of all animals when undergoing preparative techniques shall be supervised by a properly qualified veterinarian or other biological scientist competent in such matters.

4. All animals must receive every consideration for their comfort; they must be kindly treated, properly fed and their surroundings kept in a sanitary condition when held for preliminary or preparative techniques.

5. Rooms in which animals are to be housed shall be provided with a floor which can be kept clean, and the room shall be lighted and ventilated. The temperature shall be held within reasonable limits. Enclosures should be of sufficient size to permit the animal used to stand or lie in a normal position. It is generally conceded that animals maintained for long periods are in better physiological condition if they exercise regularly. Species housed out of doors shall be given adequate protection from direct sunlight or inclement weather.

6. The food and water supplied to all animals must be palatable and acceptable and of sufficient quantity and proper quality to maintain the animal's good health.

7. In any procedure likely to cause discomfort the animal shall be anesthetized and maintained in that condition until the procedure is ended. A DVM must be in attendance.

8. The care and housing of individual species should be in accordance with the recommendations of the Institute of Laboratory Animal Resources (NAS-NRC) as these are issued or revised.

APPENDIX H

Summary

of

Sensor and Platform Capabilities

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Appendix H contains more detailed data on Wildlife Monitoring sensors and sensor platforms. The following tables are included:

TABLE 9.– WAVELENGTH AND FREQUENCY RANGES OF OPERATION FOR REMOTE SENSORS

	Spectral region	Band	Wavelength	Frequency	Common applicable imaging sensors
	Microwave	Active (radar) { (UHF) (SHF) Passive	10 cm to 1 m 1 to 10 cm 1 mm to 1 cm	300 MHz to 3 GHz 3 to 30 GHz 30 to 300 GHz	Scanning antennas with radio frequency receivers
Optical	Infrared	Far IR Intermediate Near IR	8 µm to 1 mm 3 to 8 µm 0.78 to 3 µm	300 GHz to 37.5 THz 37.5 to 100 THz 100 to 385 THz	Scanners with infrared detectors; various image tubes (not very satisfactory)
		Near IR	0.78 to 3 µm	100 to 385 THz	Photographic film to approx. 1 µm; scanners with infrared detectors; various image tubes
	Visible		0.38 to 0.78 µm	385 to 789 THz	Photographic film; scanners with photomultiplier detectors; television
	Ultraviolet	Near UV Intermediate UV	315 to 380 nm 280 to 315 nm	789 to 952 THz 952 to 1008 THz	Photographic film; quartz lenses; scanners with photomultiplier detectors; image-converter tubes
		Far UV Vacuum UV	100 to 280 nm 4 to 100 nm	1008 to 3000 THz 3000 to 75,000 THz	These wavelengths do not penetrate the Earth's atmosphere significantly to be useful for agricultural remote sensing

TABLE 10.– AIRCRAFT BORNE ACQUISITION SYSTEMS

SENSOR SYSTEM	AIRCRAFT PLATFORM	ALTITUDE	AVAILABLE	SWATH WIDTH	INSTANTANEOUS FIELD OF VIEW	RESOLUTION	IMAGE AREA	COVERAGE RATE	SPECTRAL REGION	WEIGHT
2 1/4 INCH (70 mm) FILM FORMAT CAMERA 40 mm (WIDE ANGLE) LENS BLACK & WHITE FILM OR MULTIPLE FILTERED BANDS ALSO COLOR FILM	U-2 B-57	20 km 65,000 ft	NOW	27 km	70 88 DIAG	14 m	800 km^2	100,000 km^2/5 hr	VISIBLE .38-.92 μm	
	LEARJET 990	12.5 km 41,000 ft	NOW	18 km	"	9 m	360 km^2	80,000 km^2/5 hr		
	QUEEN-AIR	5 km 15,000 ft	NOW	7 km	"	3.5 m	50 km^2	10,000 km^2/5 hr	"	
	QUEEN-AIR	1 km 3000 ft	NOW	1.5 km	"	65 m	2 km^2	2200 km^2/5 hr	"	
2 1/4 INCH (70 mm) FILM FORMAT CAMERA 150 mm (TELEPHOTO) LENS	U-2 B-57	20 km 65,000 ft	NOW	7 km	29 DIAG	3.5 m	45 km^2	26,000 km^2/5 hr		
	LEARJET 990	12.5 km 41,000 ft	NOW	4.7 km	"	2.4 m	[illegible] km^2	21,000 km^2/5 hr	"	
	QUEEN-AIR	5 km 15,000 ft	NOW	1.8 km	"	0.9 m	3 km^2	2600 km^2/5 hr	"	
	QUEEN-AIR	1 km 3000 ft	NOW	35 km	"	0.2	13 km^2	510 km^2/5 hr		
9" × 9" FILM FORMAT CARTOGRAPHIC CAMERA 6" FOCAL LENGTH LENS	U-2 B-57	20 km 65,000 ft	NOW	30 km (16 nm)	82	6 m 20 ft	900 km^2 (258 nm^2)	110,000 km^2/5 hr		300 lb
	LEARJET 990	12.5 km 41,000 ft	NOW	19 km	"	4 m	360 km^2	84,000 km^2/5 hr		

TABLE 10.– AIRCRAFT BORNE ACQUISITION SYSTEMS (Concluded)

SENSOR SYSTEM	AIRCRAFT PLATFORM	ALTITUDE	AVAILABLE	SWATH WIDTH	INSTANTANEOUS FIELD OF VIEW	RESOLUTION	IMAGED AREA	COVERAGE RATE	SPECTRAL REGION	WEIGHT
9" - 18" FILM FORMAT FRAMING CAMERA 24" FOCAL LENGTH LENS	U-2 B-57	20 km 65,000 ft	USAF	15 km 8 nm		58 m 19 ft	110 km^2 32 nm^2	56,000 km^2/5 hr	VISIBLE .33-.92 μm	225 lb
	LEARJET 980	12.5 km 41,000 ft	USAF	9.4 km 5 nm		.37 m	44 km^2	41,000 km^2/5 hr	"	"
9" - 9" FILM FORMAT FRAMING CAMERA 24" FOCAL LENGTH LENS	U-2 B-57	20 km 65,000 ft	NOW	7.5 km 4 nm		58 m 1.9 ft	55 km^2 16 nm^2	28,000 km^2/5 hr	"	"
	LEARJET 980	12.5 km 41,000 ft	NOW	4.7 km 2.5 nm		37 m	22 km^2 6.3 nm^2	2100 km^2/5 hr	"	"
OPTICAL BAR PANORAMIC CAMERA 24" FOCAL LENGTH LENS	U-2 B-57	20 km 65,000 ft	NOW	57 km 30.8 nm		58 m (NADIR) 1.9 ft (NADIR) 5.6 ft (EDGE)	230 km^2 65 nm^2	210,000 km^2/5 hr	"	410 lb
	LEARJET 980	12.5 km 41,000 ft	NOW	36 km 19.5 nm		37 m (NADIR)	90 km^2 26 nm^2	160,000 km^2/5 hr	"	"
MULTISPECTRAL SCANNER	U-2 B-57	20 km 65,000 ft	NOW	28 km 15 nm	6.7 10^{-5} 1.4 10^{-4} ON IR	40 m 130 ft	–	100,000 km^2/5 hr	.37-1.1 μm 1.2-13 μm	275 lb (1 TAPE) 380 lb (2 TAPES)
	LEARJET 980	12.5 km 41,000 ft	NOW	18 km 9.4 nm		25 m 82 ft	–	79,000 km^2/5 hr		"
INFRARED SCANNER	LEARJET 980	"	?	25 km	8.8 10^{-5} rad	2.2 m 0.6 K	–	110,000 km^2/5 hr		325 kg W/POWER
COHERENT SIDE LOOKING RADAR	LEARJET 980	"	?	25 km		10 m	–	110,000 km^2/5 hr		385 kg W/POWER

TABLE 11.– ERAP CAMERA SENSOR SYSTEMS (JANUARY 1974)

CONFIGURATION	CAMERA TYPE	FOCAL LENGTH (inches)	FORMAT (inches)	COVERAGE (per frame) @ 65,000'MSL (nmi)	NOMINAL GRD (ft)	REMARKS
VINTEN SYSTEMS A&B	VINTEN (4)	1 3/4	2 1/4 × 2 3/16	14 × 14	30-50	4 CAMERAS; NORMAL FILTRATION 475-575 nm 580-680 nm 690-760 nm 510-900 nm
I^{2}S MULTISPECTRAL CAMERA	I^{2}S MARK I	3.94 (100mm)	3.5 × 3.5 (4 IMAGES)	9 × 9	20-30	4 SPECTRAL BANDS 400-700 nm 470-590 nm 590-680 nm 740-900 nm
RC-10	WILD-HEER BRUG RC-10	6	9 × 9	16 × 16	20-25	"METRIC" CAMERA INTERCHANGEABLE 12" LENS CONE
B-1 CONFIGURATION	HC 730V HC-730L HC 730R HR 732	6 6 6 24	9 × 9 9 × 9 9 × 9 9 × 18	16 × 16 – – 4 × 8	20-25 – – 2-8	VERTICAL LEFT OBLIQUE RIGHT OBLIQUE VERTICAL OR ROCKER MODE
B-2 CONFIGURATION	HR 732V HR 732L HR 732R	24 24 24	9 × 18 9 × 18 9 × 18	4 × 8 – –	2-8 – –	VERTICAL LEFT OBLIQUE RIGHT OBLIQUE
B-3 CONFIGURATION	HR 732F HR 732C HR-732R	24 24 24	9 × 18 9 × 18 9 × 18	4 × 8 4 × 8 4 × 8	2-8 2-8 2-8	FORWARD CAMERA CENTER CAMERA REAR CAMERA MULTI EMULSION OR MULTISPECTRAL

TABLE 12.– FUTURE ERAP SENSOR SYSTEMS (JANUARY 1974)

CONFIGURATION	DESCRIPTION	REMARKS
DUAL RC-10 CONFIGURATION	TWO RC-10 CAMERA; MATCHED 6-INCH FL OR 6-INCH AND 12-INCH FL	DUAL SCALE OR DUAL EMULSION
MODIFIED A-1 CONFIGURATION	RC-10 CAMERA REPLACING HC-730V CAMERA	IMPROVED 6-INCH FL VERTICAL CAMERA
"B" SYSTEM	HR-738 CAMERA–36-INCH FL, 18 × 18-INCH FORMAT (SPLIT 9 × 18 TWO FILM ROLLS); ROCKING OPTICS FOR VERTICALS AND OBLIQUES	MULTI-OPERATIONAL MODES (SELECTIVE)
OPTICAL BAR PANORAMIC	KA-80A PANORAMIC CAMERA, 24-INCH FL, 13.5 LENS; 120° SCAN, FORMAT 4-1/2 × 50 INCHES; MONO OR STEREO MODES; AEC; 135 1/mm	HIGH RESOLUTION WIDE AREA COVERAGE
THERMAL SCANNER	HRB-454 IR MAPPER; DUAL CHANNEL– 5-8 MICRONS AND 8-12 MICRONS, 90° SCAN, 1 mrad IFV; 70 mm FILM	FOR EVALUATION AS IR (THERMAL) SENSOR
THERMAL SCANNER	D-4 IR SCANNER, SINGLE CHANNEL, 8-14 MICRONS, 90 mm FILM, 1/2 mrad IFV	FOR EVALUATION AS IR (THERMAL) SENSOR

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TABLE 13.– SATELLITE BORNE ACQUISITION SYSTEMS

SENSOR SYSTEM	SPACECRAFT	FIRST LAUNCH	ORBIT	APPLICATION	TYPE	SCAN ANGLE	INSTANTANEOUS FIELD OF VIEW	SPECTRAL REGION	NADIR RESOLUTION	SWATH WIDTH	TIME FOR COMPLETE COVERAGE
HIGH RESOLUTION INFRARED RADIOMETER (HRIR)	NIMBUS I, II, III	8-28-64	1100 km (600 n mi) POLAR SUN SYNCHRONOUS (NOON)	DAY NIGHT CLOUD MAPS AND CLOUD TEMPERATURE	CROSS COURSE ROTATING MIRROR	45 r/min 2.060 rad (118°)	7.9 mr	0.7-1.1 μm	8.7 km (28,800 ft)	5300 km	1 day
							7.9 mr	3.4-4.2 μm	8.7 km (28,800 ft)		
MEDIUM RESOLUTION IR RADIOMETER (MRIR)	NIMBUS II, III	5-15-66 (NIMBUS II)	1100 km (600 n mi) POLAR SUN SYNCHRONOUS (NOON)	ALBEDO WATER VAPOR & CO_2 DIST DAY & NIGHT CLOUD MAPS CLOUD TEMPERATURE	CROSS COURSE ROTATING MIRROR	8 r/min 2.060 rad (118°)	43 mr		47 km	5300 km	1 day
SPIN SCAN CLOUD CAMERA (SSCC)	ATS I	12-6-66	35,870 km 19,400 n mi GEOSTATIONARY	DAYTIME CLOUD COVER MAPS	SPACECRAFT SPIN	100 r/min LATITUDE 0.314 rad (18°)	0.1 mr	0.47-0.6 μm	3.6 km (11,800 ft)	HEMISPHERICAL	1 HR
MULTI COLOR SPIN SCAN CLOUD CAMERA (MSSCC)	ATS III	11-5-67	35,870 km 19,400 n mi GEOSTATIONARY	THREE COLOR DAYTIME CLOUD COVER MAPS	SPACECRAFT SPIN	100 r/min LATITUDE STEP 0.314 rad (18°)	0.1 mr	0.38-0.48 0.48-0.58 μm 0.55-0.63	3.6 km (11,800 ft)	HEMISPHERICAL	1 HR
HIGH RESOLUTION SCANNING RADIOMETER (HRSR)	ITOS	1-23-70	1460 km 790 n mi	DAY NIGHT CLOUD MAPS & CLOUD TEMPERATURE	CROSS COURSE ROTATING MIRROR	48 r/min 1.920 r (110°)	2.7 mr	0.55-0.73 μm	4 km (13,100 ft)	7800 km	1 day
							5.6 mr	10.5-12.5 μm	8.2 km (26,900 ft)		

TABLE 13.– SATELLITE BORNE ACQUISITION SYSTEMS (Continued)

SENSOR SYSTEM	SPACECRAFT	FIRST LAUNCH	ORBIT	APPLICATION	TYPE	SCAN ANGLE	INSTANTANEOUS FIELD OF VIEW	SPECTRAL REGION	NADIR RESOLUTION	SWATH WIDTH	TIME FOR COMPLETE COVERAGE
TEMPERATURE-HUMIDITY IR RADIOMETER (THIR)	NIMBUS IV	4-8-70	1100 km (600 n mi) POLAR-SUN SYNCHRONOUS (NOON)	WATER VAPOR DISTRIBUTION DAY-NIGHT CLOUD MAPS, CLOUD TEMPERATURE	CROSS-COURSE ROTATING MIRROR	48 r/min 2.069 r (118°)	21 mrad	6 7 μm	23.2 km	5300 km	1 day
							7 mrad	10.5-12 5 μm	7.7 km (25,200 ft)		
MULTI-SPECTRAL SCANNER (MSS)	ERTS I,B	7-23-72	930 km (500 n mi) POLAR-SUN SYNCHRONOUS (10 a.m.)	EARTH RESOURCE SURVEY	CROSS-COURSE OSCILLATING MIRROR	15 Hz .202 rad (11.6°)	0 086 mrad	0.5-0 6 0.6-0.7 0.7-0.8 μm 0.8-1.1	0.079 km (259 ft)	180 km 100 n mi	18 days
							0.256 mrad	10 4-12.6 μm	0 237 km (776 ft)		
VERY HIGH RESOLUTION REDIOMETER (VHRR)	ITOS-D IV	10-15-72	1,460 km 790 mi POLAR SUN SYNCHRONOUS (3 p m.)	HIGH RESOLUTION DAY & NIGHT CLOUD MAPS & TEMPERATURE	CROSS-SCAN ROTATING MIRROR	400 r/min 2.007 rad (115°)	0.6 mrad	0.55-0.73 μm	0.88 km (2,880 ft)	7800 km	1 day
							0 6 mrad	10 5-12.5 μm	0.88 km (2,880 ft)		
SURFACE COMPOSITION MAPPING RADIOMETER (SCMR)	NIMBUS V	12-12-72	1100 km (600 n mi) POLAR SUN SYNCHRONOUS (NOON)	HIGH RESOLUTION MAPS OF TERRESTRIAL MINERAL CHARACTER	CROSS-SCAN ROTATING MIRROR	600 r/min 1.571 rad (90°)	0.6 mrad	0 8-1 1 μm	0 66 km (2,160 ft)	2500 km	1 day
							0 6 mrad	8 3-9 3 10.2-11.2 μm	0 66 km (2 160 ft)		
EREP MULTI-SPECTRAL SCANNER (S-192)	SKYLAB	5-73	435 km (235 n mi) CIRCULAR	EARTH RESOURCE SURVEY	IMAGE SPACE CONICAL SCAN	6000 rpm 2.09 rad (120°)	0.182 mrad	0.41-1.2 μm	0 08 km (262 ft)	1500 km	
							0 182 mrad	1 2 2.35 10.2 12 5 μm	0 08 km (262 ft)		

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TABLE 13.– SATELLITE BORNE ACQUISITION SYSTEMS (Continued)

SENSOR SYSTEM	SPACECRAFT	FIRST LAUNCH	ORBIT	APPLICATION	TYPE	SCAN ANGLE	INSTANTANEOUS FIELD OF VIEW	SPECTRAL REGION	NADIR RESOLUTION	SWATH WIDTH	TIME FOR COMPLETE COVERAGE
VISIBLE IR SPIN-SCAN RADIOMETER (VISSR)	SYNCHRONOUS METEOROLOGICAL SATELLITE (SMS)	10-73	35,870 km (19,400 n.mi.) GEOSTATIONARY	HIGH RESOLUTION DAY & NIGHT CLOUD MAPS & TEMPERATURE	SPACECRAFT SPIN & LATITUDE STEP OF MIRROR	100 r/min 0.314 rad (18°)	0.025 mrad	0.55-0.75 μm	0.9 km (2,950 ft)	HEMISPHERICAL	1 HR
							0.025 mrad	10.5-12.6 μm	0.9 km (2,950 ft)		
VERY HIGH RESOLUTION RADIOMETER (VHRR)	ATS F	1974	35,870 km (19,400 n.mi.) GEOSTATIONARY	HIGH RESOLUTION DAY & NIGHT CLOUD MAPS	RASTER SCAN OF SERVO STEPPED GIMBALLED FLAT MIRROR		0.3 mrad	0.55-0.7 μm	11 km (36,000 ft)		"
							0.3 mrad	10.5-12.5 μm	11 km (36,000 ft)		
ADVANCED VERY HIGH RESOLUTION RADIOMETER (AVHRR)	TIROS-N	4-78	1475 km (806 n.mi.)				0.86 mrad	0.5-0.7 / 0.75-1.0 μm	0.81 km (2,660 ft)		
							2.66 mrad	6.5-7.0 μm	3.9 km		
							0.86 mrad	10.5-12.5 μm	0.81 km		
THEMATIC MAPPER (TM)	EOS-A	1-79 (?)	914 km (494 n.mi.) POLAR SUN SYNCHRONOUS (9:30 a.m.)				0.033 mrad	0.5-0.6 / 0.6-0.7 / 0.7-0.8 / 0.8-1.1 / 1.55-1.75 / 0.8-2.35 / 10.4-12.6 μm	30 m	185 km / 100 n.mi.	17 days
HIGH RESOLUTION POINTABLE IMAGER (HRPI)	EOS-A	1-79 (?)	914 km (494 n.mi.) POLAR SUN SYNCHRONOUS (9:30 a.m.)				0.11 mrad	0.5-0.6 / 0.6-0.7 / 0.7-0.8 / 0.8-1.1	10 m	48 km	

TABLE 13.– SATELLITE BORNE ACQUISITION SYSTEMS (Concluded)

SENSOR SYSTEM	SPACECRAFT	FIRST LAUNCH	ORBIT	APPLICATION	TYPE	SCAN ANGLE	INSTANTANEOUS FIELD OF VIEW	SPECTRAL REGION	NADIR RESOLUTION	SWATH WIDTH	TIME FOR COMPLETE COVERAGE
SYNTHETIC APERTURE RADAR (SAR)	EOS A	1'79 (?)	914 km (494 n mi) POLAR SUN SYNCHRONOUS (9 30 a m)			DEPRESSION ANGLE 40 60			20 m	61 2 km 33 n mi	17 days
VERY HIGH RESOLUTION SCANNER	SEOS	1 81 (?)	35 870 km (19 400 n mi)				0 006 mrad 0 014 mrad	0 5 0 7 0 8 1 2 μm 0 8 1 2	2 km 5 km		1 HR
							0 042 mrad 0 160 mrad	3 4 4 1 10 5 12 5 μm 6 3 6 7	1 5 km 5 0 km		

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TABLE 14.– SKYLAB ERAP SENSOR SYSTEMS

S-190A	MULTISPECTRAL PHOTOGRAPHIC FACILITY 6 BANDS PHOTOGRAPHIC FILM (4 B&W, 2 COLOR) 6-INCH FL, 70mm FILM (2-1/4" × 2-1/4") NOMINAL GROUND SCENE COVERAGE–88 × 88 NAUTICAL MILES NOMINAL GRD–150-300 FEET (FILM DEPENDENT)
S-190B	EARTH TERRAIN CAMERA VARIED FILM TYPES (COLOR AND B&W) 18-INCH FL, 5" FILM (4-1/2" × 4-1/2") NOMINAL GROUND SCENE COVERAGE–59 × 59 NAUTICAL MILES NOMINAL GRD–37-150 FEET (FILM DEPENDENT)
S-191	INFRARED SPECTROMETER (NON-IMAGING SYSTEM) 2 BANDS .4-2.4 μm, 6.2-15.5 μm 1 MRAD IFV (LOW RESOLUTION)
S-192	MULTISPECTRAL SCANNER 13 CHANNELS–.4-12.5 μm 0.182 MRAD IFV (260 FEET), 110° SCAN MAGNETIC TAPE (DIGITAL)
S-193	MICROWAVE SYSTEM ACTIVE AND PASSIVE MICROWAVE 13.8-14.0 GHz LOW RESOLUTION–6 NAUTICAL MILES CONE
S-194	L-BAND RADIOMETER MICROWAVE RADIOMETER–21 cm RESOLUTION–60 NAUTICAL MILES DIAMETER CIRCLE

TABLE 15.– SATELLITES PRESENTLY IN ORBIT

Spacecraft	On-orbit Weight (lb)	Launch Vehicle	Availability	Freq (MHz)	Transponder: Bandwidth (MHz)	Transponder: Power Amplifier	Transponder: Type	Transponder: Number	Antenna: Type	Antenna: Gain	EIRP per Transponder	Cost ($Millions): Satellite	Cost ($Millions): Launch
ATS-1	775	Atlas-Agena D	Now-Positioned at 150°W longitude. Launched 12/6/66. 3-year design lifetime limited propulsion capability left	Up 6000 Down 4000	25	Two 4-watt TWTS independent or summed	IF translation soft limiter[1]	2	Rec collinear array Xmit electronically despun phased array	Rec 7.8 dB Xmit 14 dB[5]	21.7 dBW (2 TWTs)	[illegible]	[illegible]
ATS-3	[illegible]	Atlas-Agena D	Now-Positioned at 69°W longitude Launched 11/5/67 3-year design lifetime Active and useable	Up 6000 Down 4000	25	Two 12-watt TWTS independently employed	IF translation soft limiter[1]	1	Mechanically despun	17.2 dB[5]	26.2 dBW (1 TWT)	[illegible]	[illegible]
				Up 6000 Down 4000	25	Two [illegible]-watt TWTS independently employed	IF translation [illegible] limiter	1			22.1 dBW (1 TWT)		
INTELSAT II	132	Thrust augmented delta	Approximately 18 months after a new item procurement decision. *3-year design lifetime.	Up 6000 Down 4000	126	Four 6-watt TWTS. Any three used simultaneously	RF translation linear (redundant backup available)	1	Rec. Omni Xmit multiple element biconical horn (12 torroidal)	Rec 6 dB Xmit 6 dB	15 dBW	[illegible][2]	[illegible][2]
INTELSAT III	3[illegible]4	Thrust augmented delta	Approximately 18 months after a new item procurement decision. 5-year design lifetime.	Up 6000 Down 4000	225	One 10-watt TWT	RF translation linear	2	Mechanically despun	14 dB[5]	22 dBW	[illegible]	[illegible][2]
IDCSP	102	Titan IIIC[3]	Approximately 18 months after a new item procurement decision. 3-year design lifetime.	Up 8000 Down 7000	26	Two 2.5-watt TWTS independently employed	IF translation hard limiter	1	Dual biconic (torroidal pattern)	3 dB[5]	7 dBW	[illegible]	[illegible][2][3]
TACSATCOM	1620	Titan IIIC	Approximately 18 months after a new item procurement decision.	Up 8000 Down 7000	10	Three 20-watt TWTS any two used simultaneously	IF translation hard limiter	1	Mechanically despun microwave horn	15 dB[5]	30 dBW	[illegible][2]	[illegible][2]
				Up 300 Down 250	0.5	200-watt solid state	IF translation hard limiter	1	Mechanically despun five element helix array	15 dB[5]	[illegible] dBW		
SKYNET	280	Thor-Delta	Approximately 18 months after a new item procurement decision. 5-year design lifetime.	Up 8000 Down 7000	20[4]	Two 3-watt TWTS independently employed	IF translation hard limiter	1	Mechanically despun	15 dB[5]	14 dBW[4]	[illegible][2]	4.[illegible][2]
					2[4]						14 dBW[4]		
NATO	280	Thor-Delta	Approximately 18 months after a new item procurement decision 5-year design lifetime	Up 8000 Down 7000	20[4]	Two 3-watt TWTS independently employed	IF translation hard limiter	1	Mechanically despun	15 dB[5]	16.3 dBW[4]	[illegible][2]	4.[illegible][2]
					2[4]						[illegible] dBW[4]		

NOTES. (1) One of three modes possible with this transponder. Also has modulation conversion and spacecraft high rate data transmission modes.
(2) Preliminary estimates based on past costs. Costs of future items may prove to be higher.
(3) Eight of these spacecraft have commonly been deployed into near synchronous orbits by one launch vehicle.
(4) Transponder has two channels.
(5) Antenna provides earth coverage from synchronous altitude.

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TABLE 16.– PLANNED OR PROPOSED SATELLITES

Spacecraft	On-orbit Weight (lb)	Launch Vehicle	Availability	Transponder: Freq (MHz)	Transponder: Bandwidth (MHz)	Transponder: Power Amplifier	Transponder: Type	Transponder: Number	Antenna Type	Gain	EIRP per Transponder	Cost ($ Millions): Satellite	Cost ($ Millions): Launch
ATS-Y-1	[illegible]5	Atlas-Agena D	Approximately 12 months after an item assembly decision. 5-year design lifetime.(1)	Up 6000 Down 4000	25	Two 4-watt TWTs independent or summed	IF translation soft limiter	2	Rcv [illegible] linear array Xmit Electronically phased array	Rcv [illegible] dB Xmit 14 dB (earth coverage)	21 dBW (two TWTs)	[illegible]	11
ATS-F & ATS-G(2)	1400-1900	Titan III-C	Launch of ATS-F expected in Feb. 1973. 5-year design lifetime. Must complete with presently planned experiments.	Up 6000 Down: 4000	40	Undefined	IF translation soft limiter	1	30 ft parabolic dish plus an earth coverage horn used only at C band	Xmit 19 dB earth coverage & 47-dB narrow beam	Earth coverage 2[illegible] dBW, [illegible] beamwidth [illegible] dBW		
				Up [illegible] Down. 2100	40	Undefined	IF translation soft limiter	1		41-dB narrow beam	1.[illegible]° beamwidth 4[illegible] dBW	[illegible]	[illegible]
				Up 1600 Down. 1500	46	Undefined	IF translation soft limiter	1		38.5-dB narrow beam	1.6° beamwidth 38 dBW		
				Up 6000 Down 850	40	Undefined	IF translation hard limiter	1		Xmit 33.5-dB narrow beam	2.8° beamwidth 48 dBW		
INTELSAT III 1/2(3)	330	Thrust Augmented Delta	Approximately 18 months after a new item procurement decision. 5-year design lifetime.	Up 6000 Down 4000	25	One 7-1/2 watt TWT	RF translation linear	2	Mechanically despun parabolic reflector supplying	Undefined(3)	[illegible] dBW at [illegible]° beamwidth points[illegible]	[illegible]	[illegible]
INTELSAT III (modified)(4)	419	Thor-Delta 903	Approximately 18 months after a new item procurement decision 5-year design lifetime.	Up 6000 Down 4000	38	One 5-watt TWT	RF translation linear	[illegible]	Earth coverage horn plus two 5.1°x6.5° beams from one parabolic reflector Mechanically despun	Narrow beam Xmit 27.[illegible] dBW	Narrow beam 3[illegible] dBW(4)	[illegible]	[illegible]
INTELSAT IV	1584	Atlas-Centaur	Approximately 18 months after first launch scheduled for early 1971. 5-year design lifetime.	Up 6000 Down 4000	36	One 10-watt TWT	RF translation linear	12	Mechanically despun Two earth coverage plus two 4.5° spot beam antennas.	Xmit 15-dB earth coverage & 27-dB spot beam	Earth coverage 2[illegible] dBW, Spot beam 3[illegible] dBW	1[illegible]	1[illegible]
TELESAT(5)	600	Thor-Delta 904	Approximately 18 months after first launch (expected by late 1972). 5-year design lifetime.	Up 6000 Down 4000	36	12 5-watt TWTs independently employed	RF translation linear	---	Mechanically despun single 3°x8° spot beam antenna	Xmit 2[illegible] dB	3[illegible] dBW	8	[illegible]
Canadian Applications(6)		Titan III-C	Approximately 18 months after first launch (expected by 1974).	Up: 12,200 Down: 11,700	---	Up to 200 watts of power possible	---	---	Multiple beams expected	Up to 43 dB possible	55 to [illegible] dBW levels	Up to 2[illegible] possible	Up to 2[illegible] possible
DSCS Phase II	1050	Titan III-C(7)	Approximately 18 months after first launch (expected early in 1971). 5-year design lifetime.	Up 8000 Down 7000	125	One 20-watt TWT	RF translation quasi-linear	1	Mechanically despun earth coverage antenna	16 dB	28 dBW hard limiting	10	11[illegible]
				Up: 8000 Down 7000	185	One 20-watt TWT	RF translation quasi-linear	1	Two mechanically despun 3° narrow beams	3[illegible] dB	44 dBW hard limiting one beam on, 38 dBW two beams		

NOTES (1) This spacecraft exists in disassembled form within NASA/GSFC. Estimates are based on assembling the various subsystems to provide an ATS-1 type spacecraft.
(2) The contract for development of this spacecraft has just been awarded. These characteristics should therefore be considered preliminary.
(3) A NASA-proposed modification to INTELSAT III. Exact antenna beamwidth has not been precisely defined.
(4) A TRW 1 September 1970 proposal for modifying the INTELSAT III spacecraft. Two elliptical beams providing about the same ERIP can be obtained on one parabolic dish.
(5) This is the Canadian Domestic Satellite. The contract for development has just been awarded. The characteristics shown are based on precontract award expectations.
(6) This is a proposed Canadian satellite that is at present only a concept being considered. Its characterization is therefore incomplete.
(7) It is planned to launch two of these spacecraft on one launch vehicle, and estimates are based on employing this approach.

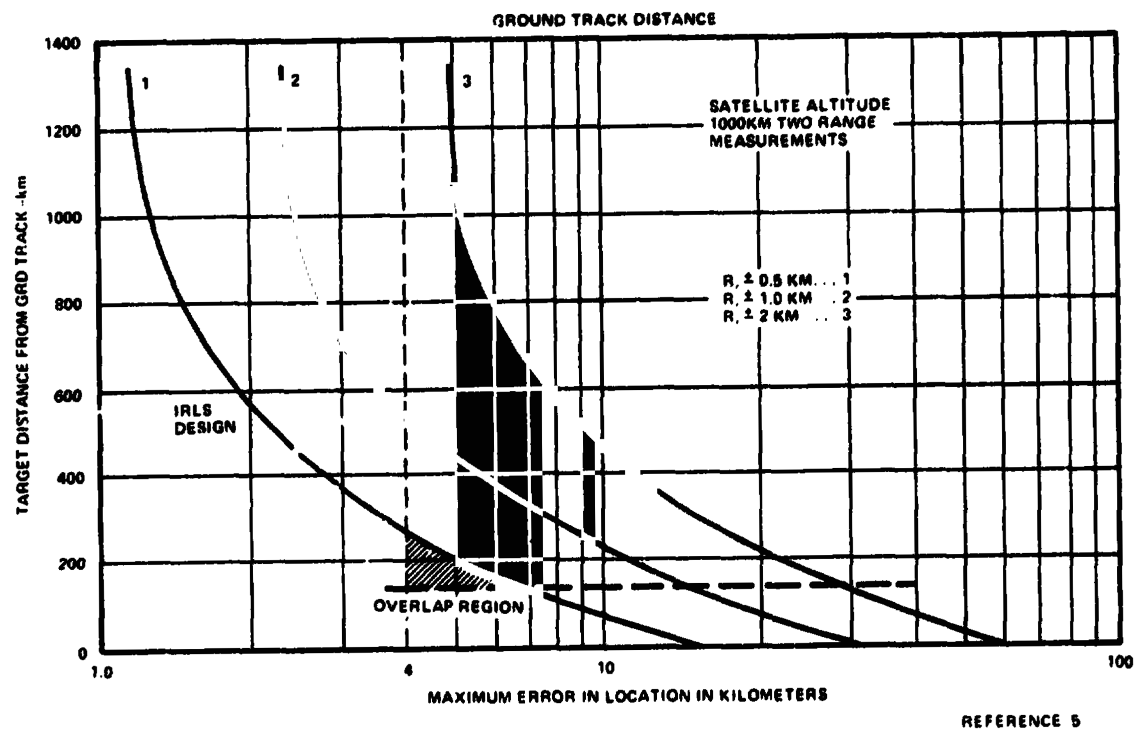

Figure 33.– Calculated location uncertainty as a function of target distance of various range accuracies.

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